THRESHOLDS IN AVIAN COMMUNITIES AT MULTIPLE SCALES: RELATIONSHIPS BETWEEN BIRDS, FORESTS, HABITATS, AND LANDSCAPES IN THE RAY ROBERTS GREENBELT, DENTON, TEXAS

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Environmental management agencies make efforts to reduce pollution loading in streams and rivers by promoting vegetated buffer zones between human activity and water. Most of these efforts do not mesh water quality-based buffer zone width requirements with conservation and wildlife values, specifically, the use of these riparian forest corridors for wildlife dispersal between habitats in highly fragmented landscapes. Forest interior birds are of the most concern to management in riparian forests due to their population declines across much of their breeding range. This dissertation investigates the role that landscape-level and habitat-level factors play on the presence of breeding birds in riparian forests, particularly the landscape and habitat factors that are influenced by human-caused fragmentation. This study describes research at the Ray Roberts Greenbelt, Denton, Texas, that explores the relationships between the landscape and forest habitats of the Greenbelt with its breeding bird community. The major findings of this study are that bird communities in the corridor forests are associated with a greater array of factors than are bird communities in patches, suggesting that the birds of patch forests are somewhat insulated from landscape-scale effects. Also, habitat values can be maintained in corridors, but there does not seem to be a significant relationship between the bird communities and the habitat. Forest factors are the primary influences (as inferred from the number of associations and the relative strength of these associations) on the bird communities of the Ray Roberts Greenbelt. Thresholds of richness or

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF ILLUSTRATIONS

CHAPTER 1

INTRODUCTION

Healthy river corridors are a vital part of many landscapes, because they provide innumerable functions and values. Water quality, flood mitigation, pollution abatement, wildlife habitat and travel corridors, aquifer recharge, subsistence living use, recreation, and aesthetics are all well-known values of river corridors, and together provide considerable rationale for preserving them (Mitsch and Gosselink 1993; Naiman et al. 1993; Bayley 1995). Efforts are made by many management agencies to reduce pollution loading in streams and rivers by providing a vegetated buffer zone between human activity and the water. Management practices and guidelines often define these buffer zones in terms of vegetation type and minimum width needed to protect water quality (Budd et al. 1987; O'Laughlin and Belt 1995). Unfortunately, there have been few systematic attempts to define criteria that mesh water quality width requirements with conservation and wildlife values, specifically, the use of these riparian corridors for wildlife dispersal between habitats in highly fragmented landscapes. This is an important consideration, as the effect of habitat fragmentation on wildlife populations has been called "the most serious threat to biological diversity and the primary cause of the present extinction crisis" (Wilcox and Murphy 1985:884).

Habitat fragmentation is the transformation of a landscape into smaller patches and islands of ecosystem types that are isolated from each other and from larger remaining tracts of intact habitat (Harris 1984; Wilcove et al. 1986). Like many forest ecosystems throughout the United States, bottomland hardwood forests are suffering from extensive fragmentation. Broadly defined, bottomland hardwood forests are mixed hardwood or hardwood-cypress forests that grow on alluvial floodplain soils that are saturated or inundated during certain parts of the year (Gower, et al., 1984); when occurring along streams or rivers these ecosystems are also called riparian forests, particularly in the western United States. The bottomland hardwood ecosystem once extended over 6.5 million hectares in Texas prior to European settlement; it is estimated that less than 40% of this original extent still remains (Frye 1986). Intact bottomland hardwood forests are among the list of endangered ecosystems in the United States; in the past 50 years, losses of these forest have at times been greater than 120,000 ha per year (MacDonald et al. 1979, as cited in King 1996).

Birds and mammals are the primary taxa at risk of extinction from habitat fragmentation due to their relatively low population densities when compared with other taxa (Wilcox 1980), and the loss of isolated populations adds to the already accelerating erosion of global biodiversity (Schonewald-Cox et al. 1983; Soulé 1987). Avian communities are particularly suffering; of the approximately 4,500 species of birds that live in the Americas, approximately 1,000 are threatened with extinction due to human factors (The Nature Conservancy 1999).

Because of both their rich habitat components and their close proximity to major waterways (which often serve as migratory flyways), these forests provide food and shelter for an impressive array of bird species (Kellison and Young 1997). Riparian forests are typically a small part of any landscape, but they are essential habitat for many species of birds; for example, riparian areas in the western United States make up less than one percent of the total landscape but are used by more species of breeding birds than any other habitat type in north America (Knopf et al. 1988). Unfortunately, the populations of many species of breeding birds that inhabit riparian forest interiors, such as the Prothonotary Warbler (*Protonotaria citrea*) (Sauer et al. 1999), have been declining over the past several decades as their habitats become increasingly fragmented. Conner and Dickson (1997: 134) discuss these issues specifically with respect to the southeastern United States: “Forest-interior birds of [bottomland] hardwood forests … are sensitive to both the loss and fragmentation of large blocks of contiguous forest … [and] are the most vulnerable avian species to future population declines and possible extirpation.”

There is a need to continue to investigate the role that landscape-level and habitat-level factors play on the presence of breeding birds in riparian forest ecosystems, particularly with respect to the factors of a landscape and habitat that are influenced by human-caused fragmentation (such as those that might influence differences between forest corridors and larger patches of interior forest). In order to address this problem, this study describes research at the Ray Roberts Greenbelt, Denton, Texas, that explores the relationships between the landscape and forest habitats of the Greenbelt with its breeding bird community. Specific objectives of this project are as follows:

?? Characterize the landscape of the Ray Roberts Greenbelt and adjacent lands.

?? Describe the vegetation community composition of the riparian forest.

?? Characterize the habitat values and habitat suitability of the riparian forest for forest interior breeding birds using Habitat Suitability Indices for selected local forest interior bird species.

?? Evaluate species richness, diversity, distribution, and abundance of birds in the riparian forest.

?? Compare and contrast habitat and landscape factors in large patches of forest and in forest corridors.

?? Evaluate relationships between the forest interior breeding bird community and habitat and landscape factors.

?? Evaluate potential thresholds in habitat and landscape factors for promoting both general and forest interior breeding bird richness in the Ray Roberts Greenbelt.

?? Use the results of this study alongside the body of scientific literature to create design and management recommendations to support wildlife values in riparian greenbelts in other areas of the southeastern bottomland hardwood forests.

Management strategies on conservation lands are often predicated on the assumption that habitat analysis and management can be used effectively as indicators to represent and support a given set of faunal communities. If this is the case, there should be a strong correlation between the results of habitat and landscape analyses and the presence of a large proportion of native species, guilds, and communities of management interest. The potential for such a relationship between landscape and habitat variables and forest interior breeding birds in the Ray Roberts Greenbelt is explored in Chapters 6 through 8. In order to support these observations, the descriptions of the forest, forest habitat, and landscape cover in the Ray Roberts Greenbelt is described in Chapter 4. The breeding bird communities of 1999 and 2000 are described in Chapter 5. General conclusions, management recommendations, and suggestions for further research are discussed in Chapter 9.

CHAPTER 2

LITERATURE SURVEY

Introduction

The importance of large tracts of contiguous habitat to breeding birds is well substantiated in the literature (e.g., Whitcomb et al. 1981, Robbins et al. 1989, Herkert et al. 1993); many area-sensitive species are not found or do not breed successfully in landscapes where their habitat is extensively fragmented (Robbins et al. 1989, Hagan and Johnston 1992). Within forest ecosystems, landscape level factors such as size and shape of forest tract often dictate the species of birds that occupy such patches (Robinson 1988, Hagan and Johnston 1992), as well as reproductive success (Hoover et al. 1995). In riparian ecosystems, which include bottomland hardwood ecosystems, width of forested habitat adjacent to the stream or river channel strongly influences the composition of the bird community (Stauffer and Best 1980, Triquet et al. 1990, Keller et al. 1993, Croonquist and Brooks 1993, Kilgo et al. 1998). For example, Kilgo et al. (1998) investigated breeding bird communities of varying widths in South Carolina and concluded that although narrow strips can support an abundant and diverse avifauna, bottomland forest habitats at least 500 m wide are necessary to maintain the complete avian community.

Although habitat factors such as structural diversity are often strongly related to bird diversity (MacArthur and MacArthur 1961; Flather et al. 1992), Franklin (1993) argued convincingly that spatial heterogeneity is a central causal factor of faunal diversity in ecosystems, as the landscape matrix itself often explains more of the variation in diversity of fauna than within-patch factors such as site-specific habitat characteristics. Pearson (1993) and Pickett and Cadenasso (1995) have substantiated this claim with respect to birds in fragmented landscapes, while Henderson et al. (1985) have shown that the degree of connectivity between forest patches could be more important than habitat characteristics to avian communities. These studies suggest that the landscape may impose important top down constraints with respect to how birds respond to habitat-level factors.

Addressing Habitat Fragmentation with Conservation Corridors

The preservation and/or creation of habitat corridors and landscape linkages has been proposed in many places as the main tool to re-link fragmented habitat "islands." As a result, corridors have begun to move into the foreground of conservation theory (Saunders and Hobbs 1991; Hudson 1991). The emergence of corridors as a conservation strategy has been relatively recent (Harris and Atkins 1991), although the use of corridors by wildlife has been studied at least since the 1930's (e.g., Sumner 1936; Edminster 1938; Davison 1941; Petrides 1942; Dambach 1945).

Wildlife corridors that connect patches of habitat are becoming an important aspect of wildlife conservation strategy. Demers (1995) stated that "the concept of landscape connectivity has shown perhaps the greatest utility in conservation biology." Current conservation biology efforts are usually oriented around bolstering declining or inbreeding populations (Brown and Kodric-Brown 1977; Frankel and Soulé 1981) and buffering against amplified mortality or demographic stochasticity (Harris and Scheck

1991; Merriam 1991) at smaller spatial scales, and in preventing inbreeding and/or extinction of biodiversity at any scale (e.g. Brown and Kodric-Brown 1977; Frankel and Soulé 1981; Noss 1983; Noss and Harris 1986; Beier and Loe 1992; Simberloff et al. 1992). In addition, corridors have been seen as useful as they have the potential to mix successional types in a landscape, which could provide more ecological complexity and/or diversity to a region (Forman and Godron 1981; Forman and Godron 1986; Wiens et al. 1992; Turner et al. 1995). They also can increase the range of wide-ranging animals, or may provide avenues for escape from predators (Harris and Scheck 1991; Harrison 1992). On a related note, corridors can act as an alternative to human translocation of (non-human) species or individuals, in order for these species to overcome the barrier effects presented by impassable surroundings (Harris and Scheck 1991). In the absence of corridors, such translocation may be necessary to bolster isolated populations, because of local extirpation (Soulé 1991) or due to shifting habitats because of global warming or other potential changes in climate (Blyth 1991; Harris and Atkins 1991; Hobbs and Hopkins 1991). Noss (1987a, 1987b) sees the promise of landscape linkages and corridors as the connections that may return landscapes to pre-fragmentation levels of genetic interchange.

In management practice, corridor protection efforts and designs for wildlife values often rely on species' natural history and vagility information to define areas of biological importance, usually by comparing corridor width and/or length with indicator species' home range sizes and dispersal abilities (Fahrig and Merriam 1985; Knopf and Samson 1994; Tiebout and Anderson 1997). The parameter of corridor width or length would intuitively seem to be of great importance, and previous research has indicated such to be the case given certain contexts and situations (Wegner and Merriam 1979; Henderson et al. 1985; Lindenmayer and Nix 1993). For example, Croonquist and Brooks (1993) found that sensitive bird species would not occur in a riparian forest corridor unless it was at least 25 m wide; Tassone (1981) found that sensitive species did not occur in such corridors unless it was at least 50 m wide. Several studies relating corridor width to bird communities in riparian forests have found that forest need to be at least 100 m wide before they become suitable for forest birds (Hodges and Krementz 1996; Mitchell 1996; Triquet et al. 1990; Keller et al. 1993; Gaines 1974). Other studies have suggested even wider forests to support a more complete avian community: from greater than 150 m (Spackman and Huges 1995; Van der Haegen and deGraaf 1996) to greater than 500 m (Kilgo et al. 1998). In general, (sufficiently wide) corridors can be important to travel and dispersal; St. Clair et al. (1998) found that forest birds in central and eastern Canada were more likely to use forest corridors for travel—as opposed to crossing open gaps in forest cover—even if the corridor was less efficient in terms of distance and travel time.

Corridors can be essential in ways beyond simple habitat factors; Franklin (1993) argued that spatial heterogeneity is a central causal factor in ecosystems, as the landscape matrix itself (including corridors and patches or different landcover types) often explains more of the variation in diversity of fauna than within-patch factors such as site-specific habitat characteristics. Pearson (1993) and Pickett and Cadenasso (1995) have substantiated this claim with respect to birds in fragmented landscapes, while Henderson et al. (1985) have shown that the degree of connectivity between forest patches could be more important than habitat characteristics to avian communities. Research in Australia has indicated that corridors provide necessary habitat for most mammal species within particular agricultural landscapes (Downes et al. 1997).

While there has been general acceptance of corridors as an effective conservation tool (Dendy 1987; Harris and Gallagher 1989; Rosenberg et al. 1997; Beier and Noss 1998), there is a profound dearth of studies that test the effectiveness of conservation corridors (Harrison 1992; Inglis and Underwood 1992; Lindenmayer and Nix 1993), and few of these tests have yielded more than ambiguous results (Simberloff et al. 1992; Spackman and Hughes 1995). For example, Tassone (1981) showed that Neotropical migrant bird species in Virginia had strong affinities for riparian forests, but many of these species would not occupy corridors less than 50 m wide. Thus, a corridor is not necessarily known to be an aid to wildlife movement until this has been empirically determined and verified to be so (Harrison 1992). Exactly how animals use corridors in terms of habitat and movement needs to be studied, as well as movement in and out or between patches of habitat or corridor zones (Downes et al. 1997). There is also no guarantee that target species will actually use a corridor (Simberloff and Cox 1987); for example, some populations that are density-independent in a habitat island at a particular point in time probably will not disperse from their habitat (Hansson 1991), and so may not use a corridor even if one is created for them. To add to the difficulty involved with evaluating the effectiveness of corridors, different species (even those in the same guild [Reader 1988]) will respond in different ways to changes in landscape and habitat factors, and the same species can respond differently to changes in habitat variables as compared with changes at the landscape level (Fahrig and Merriam 1985; Turner et al. 1995). Such variation confounds researchers' ability to design studies that address a majority of potentialities and influential variables.

Moreover, both critics and proponents of corridor theory have noted several potential drawbacks (other than cost) of corridors. They may facilitate the spread of introduced exotic species (Forman 1991; Harris and Scheck 1991; Hobbs and Hopkins 1991; Panetta and Hopkins 1991), disease and parasites, fires, or other catastrophes (Simberloff and Cox 1987). Predators may have easier access to prey species in corridors, especially where an edge effect renders narrow corridors unusable by certain species (Ambuel and Temple 1983; Catterall et al. 1991; Hobbs 1992). Corridors with low habitat suitability could act as population "sinks," which could drain off healthy animals from "source" populations, potentially leading to a higher risk of extinction for local species (Pulliam 1988; Henein and Merriam 1990; Soulé 1991; Soulé and Gilpin 1991). The increase in suitable but marginal habitat area may lead to deleterious genetic drift and outbreeding depression among a population (Schonewald-Cox et al. 1983). However, Beier and Noss (1998) point out that no study has demonstrated the occurrence of any of these potential problems.

In conservation and management activities, problems arise because as of yet there are no standardized (least-arbitrary/most ecologically inclusive) methods for which to define corridor values that promote both native wildlife conservation and water quality. O'Neil and Carey (1986) argue convincingly that simple models will usually fail to achieve complex management objectives. Different species will respond in different ways to changes in landscape and habitat factors, and the same species will respond differently to changes in habitat variables as compared with changes at the landscape level (Fahrig and Merriam 1985; Reader 1988; Turner et al. 1995). No one standard could be used for every scenario, particularly in systems as dynamic and diverse as river corridors; each riparian system is unique and must be evaluated individually for species conservation and management (Spackman and Hughes 1995; Turner et al. 1995). The general lack of reliable knowledge of the effects and usage of corridors may lead to problems in the future, as managers who operate with unreliable and confused knowledge can hurt the very populations they try to protect (Botkin 1990). Furthermore, a corridor set aside or designed without regard to an explicit purpose may actually be detrimental to the conservation efforts that promoted the corridor (Simberloff et al. 1992; Beier and Noss 1998). While corridors have strong support in the field of conservation biology—Beier and Noss (1998: 1241) state that the "evidence from well-designed studies suggests that corridors are valuable conservation tools"—without a firm and explicit conceptual and empirical scientific base, the promotion of a corridor for conservation purposes cannot be evaluated objectively (Soulé 1991). Thus, creation and management of wildlife conservation corridors must focus on promoting specific goals relevant to the particular conservation, landscape, and habitat context.

The Problem of Scale in Ecology

In order to explore the relationships between fauna and their habitats, as well as to investigate the effectiveness of forest corridors as breeding bird habitat, the question of scale must be addressed explicitly. The essential premise of ecology is that the spatial patterns of habitats and ecosystems in a landscape exert strong influences on the distributions and population dynamics of the flora and fauna, and that these readily observable patterns are the result of basic biophysical processes (Bormann and Likens 1979; Allen and Hoesktra 1992; Weins et al. 1993; Turner et al. 1995). Ecologists seek to understand the influence of ecological processes as these processes converge into observable patterns. Unfortunately, the literature is full of disagreements over the processes that lead to observable patterns; for example, the explanations of the processes driving vegetative succession have been explained differently by different scientists, though the patterns they explore are similar (Cale et al. 1989). These disagreements can be traced to implicit (and thus undefined) definitions of scale in the different studies, as in general one cannot arrive at inferences about processes that span several spatial and/or temporal scales (Allen and Hoekstra 1992; Cao and Lam 1997); indeed, it is often difficult to arrive at accurate inferences even within a single scale of analysis (Cale et al. 1989).

Throughout its history as a discipline, problems such as vegetative succession have hindered the drive to make ecology a more predictive science (Allen and Hoekstra 1992). Recent advances in ecology have come from studies that explicitly acknowledge scale within their explanations of pattern (Addicott et al. 1987; Turner et al. 1989; Allen and Hoekstra 1992; King 1993; Quattrochi and Goodchild 1997). As a result, ecologists are beginning to realize the importance of the scale of observation with respect to observed patterns; some have called the relationships between pattern and scale the "central problem in ecology" (Levin 1992: 1943). Despite this understanding, ecologists are still attempting to determine the appropriate scales at which to study a pattern of interest (Cullina and Thomas 1992; Cale and Hobbes 1994).

Scale is usually defined in ecological studies as a combination of grain (the smallest unit of measure in time or space) and extent (outermost boundary of the study in time and space); sometimes the covariation between progressively distant measures is also used (e.g., Cullina and Thomas 1992). What makes integrating this concept explicitly into ecological studies so difficult is that the factors that influence ecological entities (e.g., organisms, species, ecosystems) occur at a wide range of spatio-temporal and organizational scales (Allen and Hoekstra 1992; Levin 1992). Furthermore, the results of Turner et al. (1989) and Barry et al. (1999) demonstrate that quantitative measures of landscape pattern can differ nonsensically when comparisons across grains are made. Therefore, the grains and extents most appropriate any particular study will depend explicitly upon the questions the study wishes to address; in addition, the scales of study and the scales of the processes must match (Allen and Hoekstra 1992; Cale and Hobbs 1994). In addition, it is now widely recognized that the observer (i.e., the scientist) is an integral part of any particular study, and thus the observer introduces perceptual biases into every study. Thus, the definition of scale must be broadened to acknowledge whether a particular study is either entity-centered or observer-centered (Kotliar and Wiens 1990).

The bottom line is that there is no one "natural" scale that is appropriate for ecological studies (Allen and Hoekstra 1992; Levin 1992). Many scientists now explicitly acknowledge this difficulty; for example, in a study of landscape influences on bird distributions, McGarigal and McComb (1995: 235) state that their results "do not preclude much stronger and different relationships at finer and/or coarser scales."

In order to address the problem of scale, the study of any ecological patterns and processes requires that the grain and extent of the study area be explicitly defined. Once a study area has been defined, quantitative analysis can be performed that can assist in discovering "scale-independent" patterns (and, by inference, essential underlying processes) within the context of the study. This processes of definition is important because the formulation of the research question implicitly involves a scaling operation, which thus fixes the realm of possible outcomes (Allen and Hoekstra 1992). For example, Moloney et al. (1992) describe research that has explored the processes behind the distributional patterns of krill in the Antarctic Ocean. One factor, phytoplankton (krill food) distribution, was found to be correlated to water temperature and fluorescence at all scales, which suggested to the researchers that fluid dynamics provided a sufficient explanation for phytoplankton distribution, and was thus (in the context of their study) scale-independent (Weber et al. 1986, cited in Moloney et al. 1992). However, while at broad spatial scales the distribution of krill could be explained by these bio-physical constraints, at smaller scales their distribution was strongly influenced by aggregation behavior (Levin et al. 1989, cited in Moloney et al. 1992); thus krill distribution was strongly scale-dependent.

Allen and Hoekstra (1992) point out that trying to find the "real scale" of nature will generate a great deal of data with little applicability. What must now be done in ecology, if the results of any research program are to be generalized beyond the study area, is that every study must begin by explicitly defining the ecological question as well as the spatial and temporal extent of the study. When the scale of analysis is thus fixed, sensible patterns emerge, and prediction becomes possible.

Defining Landscape "Extent"

Complicating the need to evaluate a wide variety of variables, different patterns in the ecology of a landscape emerge at different spatial scales of sampling and analysis (Cale and Hobbs 1994; Stohlgren et al. 1996; Bissonette 1997). Some studies have indicated that many metrics used to quantify landscape pattern can be reduced to simpler sets of a few univariate metrics that can still explain the majority of variation in landscape spatial pattern (Riitters et al. 1995), though it is not clear whether such variation is accounted for in the evaluation of the floral and faunal communities that reside in these patches.

Thus, in order to measure landscape factors, the grain and extent of the study area must be defined explicitly prior to any analysis. Grain is usually defined by the availability of remotely sensed images or databases, and is thus usually fixed at a given size (e.g., 20 m for SPOT satellite data). Extent is harder to define because so far it is unclear as to how much of a given landscape influences particular bird species; it is thought that the scale of influence depends upon the life history characteristics of each species (Freemark et al. 1995, Villard et al. 1999), which can vary to a small area for some year-round resident birds to as much as the length of two continents for long distance migrants (Hagan and Johnston 1992). Most efforts at defining the extent of a study area to determine its influence on the native fauna are focused at the landscape scale (10s to 1000s of km^2). In most studies, sampling points are used as window focal points that define mini-landscapes of 100s to 1000s of m^2. These windows sizes are defined in many studies relating avian communities to landscape factors, but the justification for those particular sizes are not; Tables 1 and 2, below, show the radius distances from the sample point to the edge of the window for a set of avian-landscape relationship studies. Table 2-1 lists those studies that provided some sort of biologically based rationale for their definition of the landscape extent; Table 2-2 lists the studies that provided no such justification.

Table 2-1. Landscape evaluation widows derived from the literature with justifications.

Radius	Rationale	Source
10,000 m	Cowbird home range (both sources)	Robinson et al. 1995; Knutsen et al. 1999
7,000 m	Cowbird foraging distance	Robinson et al. 1995
2,400 m	Similar to maximum foraging radius of Spotted Owls in study area	Ripple et al. 1997
1,410 m	Radius of a 6.25 square km study area (chosen to encompass most breeding dispersal of local forest birds)	Villard et al. 1999
1,000 m	Encompasses the maximum breeding home ranges or territory sizes of all bird species surveyed	Söderstrom and Pärt 2000
100 m	Day-use "territory" area of Scissor-tailed Flycatcher in study area	Certain and Schnell 2000
Variable (different at each sample point)	Distance to most distant habitat patches that influence populations of a given site; Smallest average home range size of breeding bird(s) of interest; Home ranges of individual Ruffed Grouse	Pearson 1993; McGarigal and McComb 1995; Fearer et al. 1999

Table 2-2. Landscape evaluation widows derived from the literature without biological or ecological justifications.

Radius	Rationale	Source
6,436 m	Radius of a 16 square mile research area tracking movements of waterfowl predators	Phillips et al. 1999
4,800 m	None given	Woodward et al. 1999
3,612 m	Radius of a 41 square km research area tracking movements of waterfowl predators	Horn et al. 1999
3,400 m	None given (largest window of nested	Ripple et al. 1991

	landscape windows)	
3,000 m	Used for an index of forest patch isolation; Radius of a circular 2827 ha landscape	Robbins et al. 1989; Mitchell et al. 1999
2,600 m	None given	Klute et al. 1999
2,400 m	None given	Ripple et al. 1991
2,000 m	Used for an index of forest patch isolation	Robbins et al. 1989
1,850 m	None given	Klute et al. 1999
1,784 m	Radius of a circular 1000 ha landscape	Rosenberg et al. 1999
1,766 m	Radius of a circular 980 ha landscape	Ripple et al. 1991
1,600 m	None given (largest window of nested landscape windows)	Bergin et al. 2000
1,596 m	Radius of a circular 800 ha landscape	Ripple et al. 1991
1,410 m	Radius of a 6.25 square km study area (chosen to encompass most breeding dispersal of local forest birds)	Villard et al. 1999
1,405 m	Radius of a circular 620 ha landscape	Ripple et al. 1991
1,200 m	None given	Bergin et al. 2000
1,183 m	Radius of a circular 440 ha landscape	Ripple et al. 1991
1,100 m	None given	Klute et al. 1999
1,000 m	Used for an index of forest patch isolation; Used for an index of landscape disturbance	Robbins et al. 1989; Rodewald and Yahner 1999
~892-977 m	Radius of a circular 250-300 ha landscape (represented compromise between sample size and local landscape sizes so that multivariate analysis could be performed)	McGarigal and McComb 1995
910 m	Radius of a circular 260 ha landscape	Ripple et al. 1991
800 m	None given (both sources)	Boren et al. 1999; Bergin et al. 2000
600 m	Subclass of largest window size; None given	Söderstrom and Pärt 2000; Bergin et al. 2000
500 m	None given (largest window of nested landscape windows); None given; Larger window sizes showed little difference in habitat proportions	Pearson 1993; Schmitz and Clark 1999; Certain and Schnell 2000
400 m	None given; Iowa landscapes often delineated into quarter-mile (~400 m) sections	Pearson 1993; Bergin et al. 2000
350 m	None given	Klute et al. 1999
300 m	Subclass of largest window size; None given	Söderstrom and Pärt 2000; Pearson 1993
250 m	Half size of largest radius	Certain and Schnell 2000
200 m	None given; Chosen as a finer scale of	Pearson 1993; Bergin et al.

	400 m (see above)	2000
100 m	Subclass of largest window size; None given	Söderstrom and Pärt 2000; Pearson 1993
80 m	Radius of a circular 2 ha landscape	Mitchell et al. 1999

Defining the Context to Investigate Corridor Values

In order to ecologically characterize a species' or faunal community's context sufficiently, three major factors must be evaluated: (1) the physical constraints on the ecology, such as soils, climate, landscape structure, and landform; (2) the biological and physical attributes of the biota of the area; and (3) the interactions between the biota and between the biota and the physical environment (Hunter et al. 1988; Gosz 1992). Turner et al. (1995) add considerations of socioeconomic factors to the list of variables that might influence the ecology of a landscape (or a corridor, for that matter), such as adjacent land use, road and housing density, and regional economic markets. A wide variety of variables and metrics must be evaluated at different scales if reliable knowledge is to be attained regarding the effectiveness of corridors for the conservation and management of wildlife; fortunately, the "ability to consider biodiversity in the context of the landscape provides enhanced opportunities to link population dynamics and ecosystem dynamics" (Turner et al. 1995: 29).

In order to address the problem of the diversity of data requirements needed for forest corridor evaluation, design, management, and restoration for forest interior breeding birds, this project describes and analyzes a variety of forest, landscape, and habitat variables, at several scales of resolution, in order to determine the relative importance of each of these variables in assessing the riparian forest of the Ray Roberts Greenbelt for corridor values (Chapters 4 and 5). This characterization is subsequently used to determine the important ecological thresholds based upon scale and resolution of the analysis that affect bird species occurrence within the riparian forest habitats of the Greenbelt (Chapters 6, 7, and 8). The final result of the study will be the development of a set of ecologically-based guidelines and criteria for designing, managing, restoring, and evaluating riparian forest corridors for wildlife utilization and other environmental benefits (Chapter 9).

CHAPTER 3

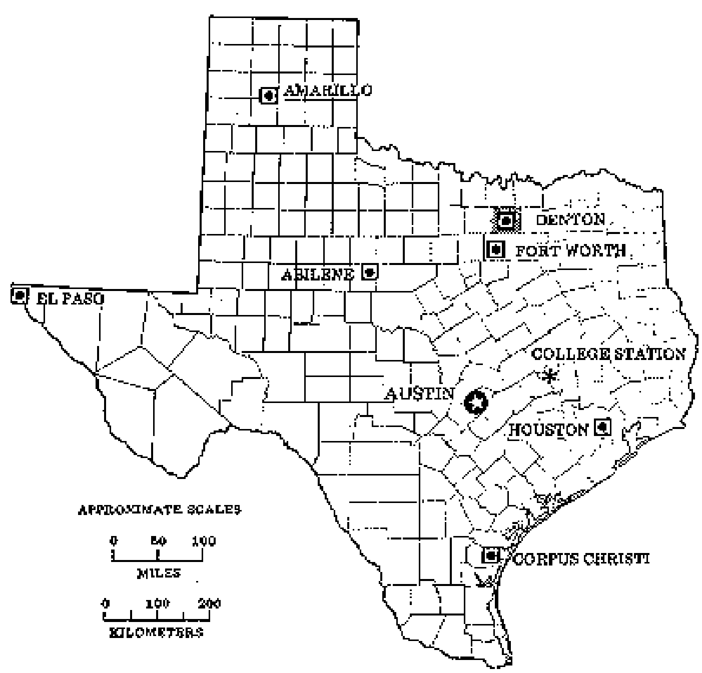
METHODS

Study Area

Denton County, Texas

Denton County occupies approximately 2450 km^2 in north-central Texas (Figure 3-1). Throughout the county, soil type is the key factor explaining native vegetation distribution (Bailey 1995). The USDA describes the climate as humid subtropical, with hot summers and mild winters (mean temperatures of 10-16°C in winter and 21-27°C in summer), with moderate rainfall of 890 mm per year and periodic drought (USDA 1980; Bailey 1995).

Figure 3-1. The location of Denton County in north central Texas.



The three primary bioregions found in Denton County include the Blackland and Grand Prairies, the Cross Timbers, and the Bottomland Hardwoods. The prairies comprise the majority of the county, and represent the southernmost extent of the tallgrass prairie of North America. Although most of the original prairie is gone, the soils are still characterized by dark, calcareous clays (USDA 1980). These prairies were once dominated by big bluestem (*Andropogen gerardii*), little bluestem (*Schizachyrium scoparium*), and dropseed (*Sporobolus* spp.) grasses, with switchgrass (*Panicum virgatum*) common along the watercourses. With the increase in agriculture and the control of fire, these prairies were gradually subsumed into shrubland or agroecosystems. Less than one percent of the original extent of tallgrass prairie still remains in Texas (Sharpless and Yelderman 1993).

The Cross Timbers is a savannah ecosystem located on a sandy, acidic stretch of soils running north-south though Denton County. The soils are variable, but are often acidic loamy sands and sandy loams, or neutral to calcareous sandy loams and silt loams (USDA 1980). The characteristic tree species of the Cross Timbers include post oak (*Quercus stellata*), blackjack oak (*Quercus marilandica*), and hickory (*Carya* spp.). The understory vegetation is similar to the Blackland Prairies (Vines 1982).

The bottomland hardwood forests occur in the floodplains of the river and creek bottoms of the county. The term "bottomland hardwoods" is most often used to describe mixed hardwood forests that grow on floodplain soils that are saturated or inundated during certain parts of the year (Gower et al., 1984). These forests grow on alluvial floodplain sites, although nonalluvial wet sites may share similar hardwood species (Hodges 1997). The characteristic tree species of the bottomlands include cedar elm

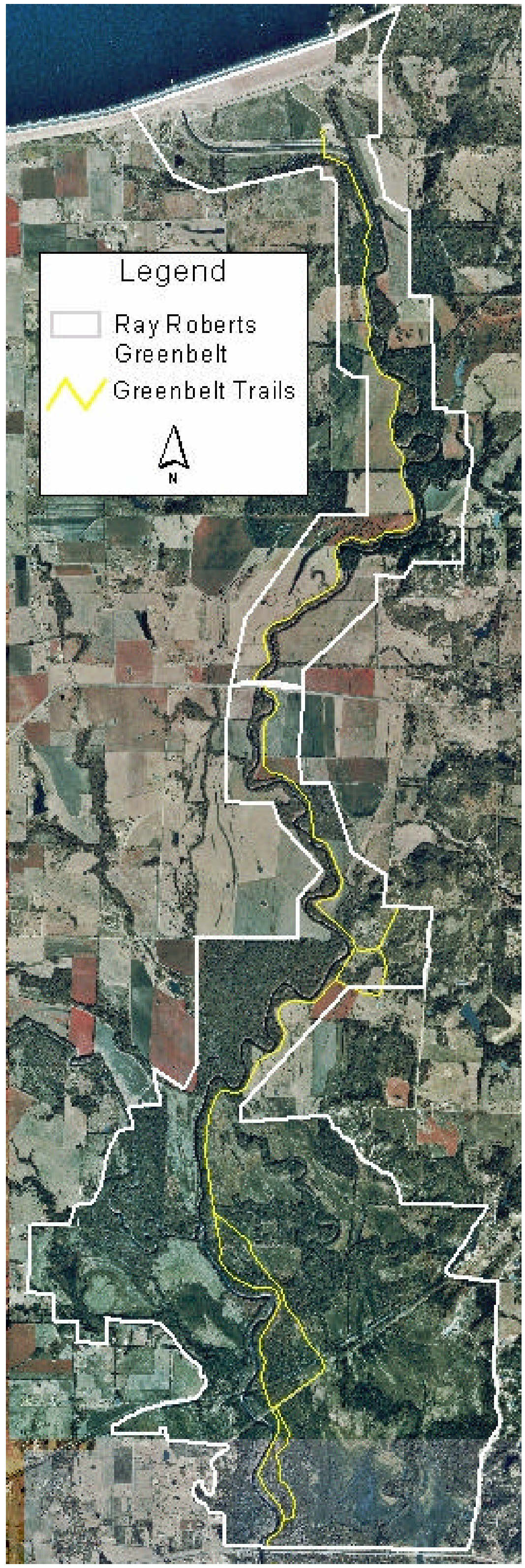
(*Ulmus crassifolia*), hackberry (*Celtis reticulata* and *C. laevigata*), and green ash (*Fraxinus pennsylvanica*).

The primary human land uses in the region are urban development and agriculture, although agriculture is gradually being replaced by urbanization from the expanding Dallas/Ft. Worth metroplex. Other recent changes in human land uses (particularly over the past 50 years) include the creation of several thousand surface acres of reservoirs for water supplies and recreation.

The Ray Roberts Greenbelt

The Ray Roberts Greenbelt is located to the northeast of Denton, situated between the upper end of Lewisville Lake at U.S. Highway 380 and the Lake Ray Roberts dam at Farm Road 455 (Figure 3-2). The Greenbelt comprises nearly 2000 ha, approximately 500 ha of which are remnant stands and corridors of bottomland forest. The Elm Fork of the Trinity River flows through the Greenbelt, traversing approximately 22 river km over the space of 16 linear km. The drop in elevation is approximately 6 m, from an elevation of approximately 168 m above mean sea level at the outflow structure below the Ray Roberts Dam to approximately 162 m at the point where the Elm Fork flows beneath U.S. 380 to enter Lewisville Lake. All three major ecosystem types within Denton County can be found within the Greenbelt study area. While the extent of the bottomland forest in the area has shrunk significantly over the past 200 years, analysis of aerial photos taken in 1970 and 1998 shows that the areal extent and patch shape/position within the riparian forest of the Greenbelt has remained almost static for the past 30 years.

Figure 3-2. The Ray Roberts Greenbelt.

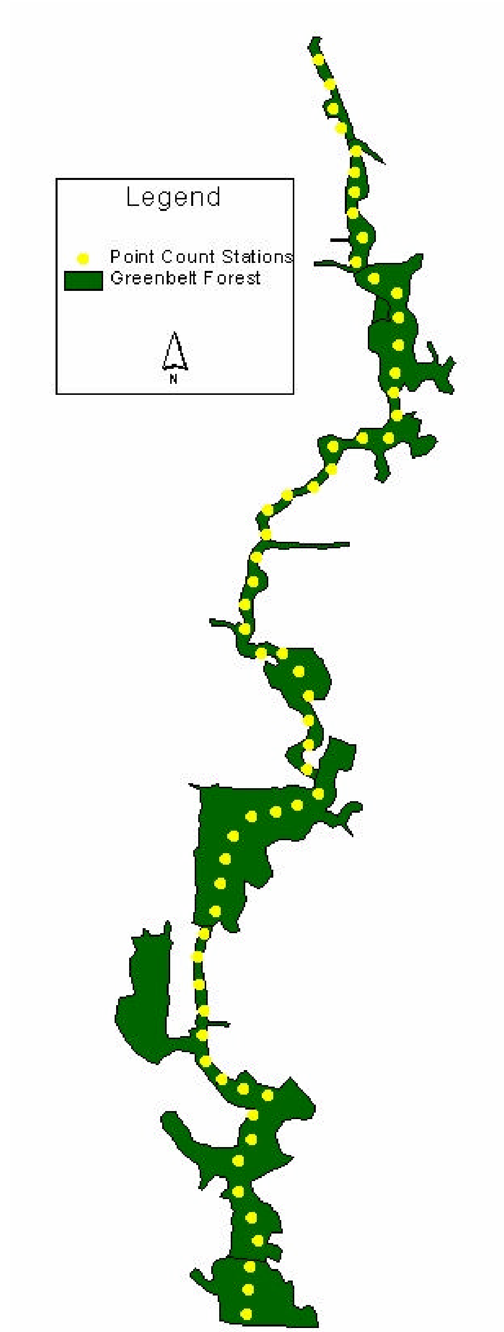


The vegetation of the riparian forest is dominated by cedar elm (*Ulmus crassifolia*), hackberry (*Celtis reticulata* and *C. laevigata*), and green ash (*Fraxinus pennsylvanica*), with occasional occurrence of bur oak (*Quercus macrocarpa*), pecan (*Carya illinoensis*), and eastern cottonwood (*Populus deltoides*) (Barry and Kroll 1997; Lindquist and Barry 1999; Barry and Kroll 1999). This elm-ash-hackberry type is recognized as a late successional stage in many bottomland hardwood forests, although in the absence of repeated disturbances it may occupy the site for two to three hundred years (Hodges 1997). Black walnut (*Juglans nigra*), chittamwood (*Bumelia lanuginosa*), bois d'arc (*Maclura pomifera*), box elder (*Acer negundo*), and hawthorn (*Crataegus* spp.) are also present in the forest. The dominant tree species occur throughout all age and size classes, while the pecan, black walnut, and chittamwood are represented by a few rare mature trees and numerous seedlings. The forb layer is a mixture of common greenbrier (*Smilax rotundifolia*), poison ivy (*Rhus toxicodendron*), coralberry (*Symphoricarpos orbiculatus*), and Virginia wild rye (*Elymus virginicus*). Livestock still graze on occasion within the forest; it is unknown what effect their browsing and trampling is having on the composition of the forest community.

Sampling Station Designation

A set of 62 permanent sampling stations were situated along a transect placed within the riparian corridor and forest patches, roughly following the course of the Elm Fork of the Trinity River. The transect was delineated so that sampling stations were equally distant from the forest edge perpendicular to the transect. Each sampling station was placed approximately 250 meters apart, in order to avoid double counting individual birds (Ralph et al. 1995). The stations were marked on a map and then located in the field using a GPS unit and evaluation of aerial photographs (Figure 3-3).

Figure 3-3. The locations of the 62 permanent point count stations in the Ray Roberts Greenbelt Forest.



Forest Phytosociological Evaluation

A set of 62 100 m^2 circular plots, with one plot placed at each permanent sampling station, was sampled for a set of forest habitat characteristics (number of canopy layers, mean height of each canopy layer, canopy coverage, tree density, tree species richness, and tree basal area). Within these plots, all stems of at least 10 cm dbh (diameter at breast height) within the plot were measured. All boles that split below 1.43 m from the base were measured as separate stems (Oliver and Larson 1990). Irregular boles were measured using the guidelines in Avery and Burkhart (1994). Importance values for each species were calculated for the forest as a whole as well as for corridor and patch subclasses (see Landscape Evaluation, below) through an averaging of relative dominance, density, and frequency of occurrence values (Brower et al. 1998). Besides providing a means by which the various species present in a forest may be weighted against one another, the importance values allow spatially distant sites to be compared.

Canopy coverage was determined using a densitometer. Number of canopy layers was determined by noting presence or absence of each of the following: ground/herb, shrub, understory, midstory, canopy, and emergents. Mean height of each layer was obtained by selecting a representative herb, shrub, or tree to measure, either directly with a meter tape (ground and shrub) or using a clinometer (understory, midstory, canopy, and emergents). Forest seral stage was recorded at each plot. For this classification, the average dbh of overstory trees, stem density, structural diversity, and species composition within 50 m were estimated. These data allowed for the classification of station’s seral stage into one of four classes (Oliver and Larson 1990): stand initiation (seedlings or saplings), stem exclusion (pole timber), understory reinitiation (saw timber), and old growth.

Complexity and foliage height diversity indices were calculated for each sampling station. The equation for the complexity index (CI) is

CI = Density x Sum of Basal Area x Canopy Layers x Species Richness x 10^{-5}

(adapted from Holdridge et al. [1971] and Shear et al. [1996]). The foliage height diversity (FHD) equation is

FHD = -? $p_i \log p_i$

where p_i = the proportion of the total canopy height of canopy layer i. (FHD is the H' diversity index [MacArthur and MacArthur 1961; Brower et al. 1998]).

Percent community similarity was the metric used to compare the phytosociological attributes of the forest between corridor and patch areas. The equation used for percent similarity (PS) is

PS = ? minimum ($p1i$, $p2i$)

where $p1i$, is the relative importance value of species *i* in class1 (corridor plots) and $p2i$ is the relative importance value of species *i* in class 2 (patch plots) (Dyer 1978; Brower et al. 1998).

Tree density and dominance, snag density and dominance, species richness, basal area, complexity index, foliage height diversity, and canopy coverage were compared between corridor and patch plots using the Mann-Whitney U test (? = 0.05).

Habitat Evaluation

The Habitat Evaluation Procedure was developed by the U.S. Fish and Wildlife Service (USFWS) in order to quantify habitat variables important to a given target species or set of target species chosen to represent the faunal communities of which they are a part (USFWS 1980a, 1980b). The target species' life history requirements are quantified into a Habitat Suitability Index (HSI) model that is specific to each animal and its primary habitat(s), and sometimes specific to a particular region. The HSI models use various habitat metrics to evaluate particular sites for habitat suitability for a given species. Each species with a HSI model is matched to a particular cover type or a set of cover types, depending upon the target species' life history requirements. The HSI model is then used to predict the habitat suitability for the site for that particular animal.

Each permanent sampling station was evaluated using the HSI models for three forest interior bird species: Hairy Woodpecker (Sousa 1987), Pileated Woodpecker (USFWS 1983), and Barred Owl (Allen 1987). These models were chosen to represent habitat values for forest interior bird species. Data were collected at each station using a radius of approximately 50 m from the point count station. Data collected to used these models included percent canopy coverage (all models), number of trees greater than 50 cm dbh (Pileated Woodpecker and Barred Owl), mean dbh of overstory trees (Hairy Woodpecker and Barred Owl), number of snags greater than 24 cm dbh (Hairy Woodpecker), number of snags greater than 38 cm dbh (Pileated Woodpecker), mean dbh of snags greater than 38 cm dbh (Pileated Woodpecker), and number of tree stumps and deadfall trees (Pileated Woodpecker). Habitat Suitability Indices were calculated at each plot using the formulas described in each model, and these values were compared between patches and corridors using the Mann-Whitney U Test (? = 0.05).

Landscape Evaluation

Patch/Corridor Delineation

Patches and corridors were delineated by digitizing the forest from the Digital Orthophoto Quarter-Quad (DOQQ) data set (Texas Orthoimagery Program 1996, see Figure 3-3). The DOQQs are digitizal and geo-referenced aerial photographs with a 1-meter ground resolution that follow the extent of USGS quadrangles. For this study, the USGS Denton East and Green Valley quads were used. Arc/INFO and ArcView software were used for this analysis.

Once the forest extent of the study area was delineated, all forest that was within 100 m of an edge was erased, leaving polygons of interior forest. The 100 m distance was chosen because edge effects that cause microclimatic variation are minimized or absent at this distance (Oliver and Larson 1990; McGarigal and McComb 1995). Sampling stations that fell within these remaining interior forest polygons were considered to be "patch" forest, while stations that did not occur in forest interior were considered to be within "corridors" of forest linking the forest patches. This method was also used to acquire the area of interior forest for each patch of forest.

Width and Distance Measures

Several distance measures were taken using the 1 m DOQQ data set, including the width of the forest at each sampling station, the distance of each station to the nearest edge, and the distance of each station to the nearest interior forest. ArcView measure tool was used to determine these distances, which were rounded to the nearest 5 meters.

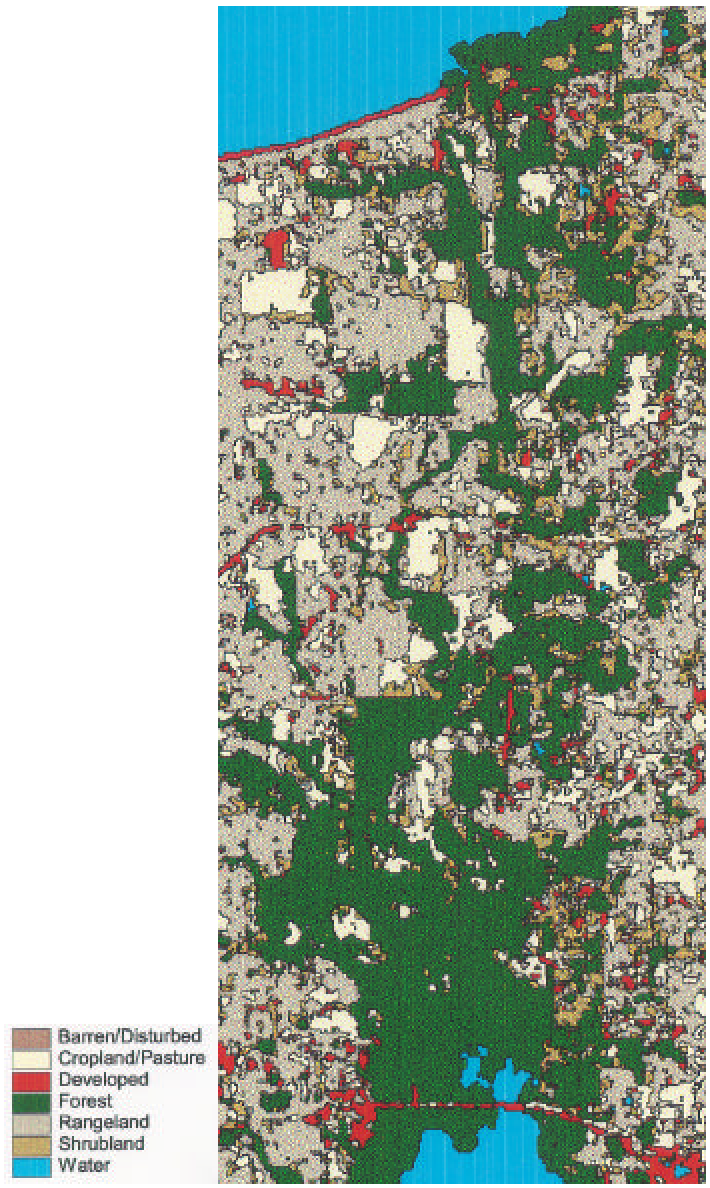
Landscape Landcover Characterization

Landcover characterization was performed using a data set is derived from 20 m spatial resolution SPOT-1 satellite imagery taken in 1997, acquired and classified by the University of North Texas' Center for Remote Sensing and Landuse Analysis (CRSLA) lab for regional environmental assessments (McDonough 1999). For this project, the landscape image was classified into six landcover classes: forest, agriculture, rangeland, developed and urban, shrubland, and water (Figure 3-4).

At each sampling station, four window sizes were used to evaluate the area and relative percent composition of each landcover class in each window (Figure 6). The four window sizes that were chosen were 100 m (to correspond with habitat and forestry analyses), 500 m (an intermediate distance with no ecological justification), 1000 m (to cover the maximum daily home range of most forest interior species), and 2000 m (to compare with the methods used and results from Robbins et al. [1989]). Area of each class was obtained for each window size at each station, and rounded to the nearest whole meter. For each station and window size, each class was then divided by the total area to obtain percent composition of each landcover class.

Comparisons of landcover composition (1) across window sizes and (2) between patch and corridor stations were done with Kruskal-Wallis ANOVA and the Mann-Whitney U Test (? = 0.05), respectively, to determine whether significant differences between classes occurred; where such differences occurred, their magnitude and particular classes were distinguished using the GT-2 test.

Figure 3-4. SPOT imagery of the Ray Roberts Greenbelt.



Avian Community Evaluation

A breeding bird survey covered the 1999 and 2000 summer breeding seasons. Each of the 62 sampling stations were sampled once each breeding season. Surveys were conducted as 10-minute extensive point counts as described by Ralph et al. (1995). Surveys were conducted beginning 0.25 hours before sunrise and up to 3.5 hours after sunrise, when wind speed was less than 20 kmph, air temperature was above 0?C, and no more than a light drizzle was falling. Sampling commenced when observers reached each sampling station. Sampling duration per point count station was exactly 10 minutes. Samplers recorded every bird species seen or heard within three distance classes (within 25 m, 26-50 m, and beyond 50 m) while sampling at each station. Bird species in the third distance class, that is, beyond 50 m, were deleted from the dataset for this analysis. Certain bird species were defined as forest interior species based upon Whitcomb et al. (1981), Ehrlich et al. (1988), Robbins et al. (1989), Stokes and Stokes (1996), and the personal experience of the research and sampling teams. Forest interior birds were chosen for this analysis due to their sensitivity to fragmentation, their general population declines across this habitat type, their status as species of management and conservation concern for several governmental and nongovernmental organizations, and their potential to serve as charismatic or “flagship” conservation species in efforts to protect, manage, or restore riparian greenbelt forests.

Abundance and frequency were determined for each bird species throughout the Greenbelt, as well as for each subclass of avian communities in patches and corridors. Shannon diversity was calculated to compare the avian communities of each subclass for each year. The Shannon diversity (H') equation is

$H' = -? \; p_i \log p_i$

where p_i = the proportion of the abundance of species *i* (Magurran 1988; Brower et al. 1998). Statistical differences between Shannon diversity in patches and corridors were compared using a t-test (? = 0.05) with the methods described in Magurran (1988). Percent community similarity (PS) was used to compare abundance and distributions of the overall and forest interior avian communities between corridor and patch areas (the equation used for percent similarity is presented in the forest evaluation section, above; in this case, abundances of bird species are substituted for tree species' importance values). Comparisons of avian metrics between patch and corridor stations were done with the Mann-Whitney U Test (? = 0.05).

Statistical Evaluations of Avian/Habitat/Landscape Relationships

The data (included as the appendix) from each sampling station were entered into a Microsoft Excel Spreadsheet and analyzed using Microsoft Excel, Statistica, Arc/Info, and ArcView software. The full data set from the 62 point count stations were also subdivided by forest class, with 43 stations occurring in forest corridors and 19 stations occurring in patch (interior) forests. Comparisons of differences in avian/habitat/landscape metrics between patch and corridor stations were done with the Mann-Whitney U Test (? = 0.05). Spearman's Rank Order Correlation was used to explore relationships between the habitat and landscape variables and avian community metrics (? = 0.05). Because most correlations between the avian communities and the landscape and habitat factors had coefficients of less than 0.5 or –0.5, correlations greater than or equal to 0.4 or –0.4 were termed strong correlations, because, in the context of this study, they were the strongest associations of those under consideration. Those strong correlations were chosen for further evaluation; significant correlations that had coefficients of less than 0.4 or –0.4 were dropped from further consideration.

In order to explore potential thresholds in avian community responses to landscape and habitat factors, the highest positive and the highest negative correlation were chosen for each avian community (all species and forest interior species, richness and abundance) in three classes: whole greenbelt, corridor forests, and patch forests. A total of 25 associations subsequently were chosen from the 53 associations that had correlation coefficients greater than or equal to 0.4 or –0.4. Two types of potential thresholds were explored. First, a second order polynomial line was fitted to the data, and the highest or lowest peak of the line was used to delineate a potential threshold for positive or negative relationships, respectively. The line was plotted on each figure with 95% confidence intervals to get a feel for the variation in the data, but the line itself was chosen for the delineation of the potential threshold. Where no peak existed in the fitted line, the maximum value of that line was chosen as a possible surrogate threshold. Second, the upper quartile of the avian community variable under consideration was chosen as a cut-off point, and a threshold is chosen for the point on the x axis where lowest data point above (for positive associations) or below (for negative associations) the upper quartile occurs.

The study design of the Greenbelt project precludes the effective use of parametric statistics, as point count stations were placed systematically in order to gain power to evaluate the effects of landscapes and habitats on breeding bird communities throughout the Greenbelt. Thus, following the methods of McGarigal and McComb

(1995), when parametric statistics are used in violation their assumptions, they are used as aids in investigative analysis and should not be seen as to imply statistical rigor.

CHAPTER 4

GREENBELT FOREST, HABITAT, AND LANDSCAPE ANALYSIS

Forest Phytosociology Results

This forest contains at least 26 different tree species, the most common of which include sugar hackberry (*Celtis laevigata*), netleaf hackberry (*Celtis reticulata*), green ash (*Fraxinus pennsylvanica*), eastern cottonwood (*Populus deltoides*), bur oak (*Quercus macrocarpa*), American elm (*Ulmus americana*), cedar elm (*Ulmus crassifolia*), and slippery elm (*Ulmus rubra*). In the understory, common trees include hawthorn (*Crataegus* spp.), box elder (*Acer negundo*), Eve's necklace (*Sophora affinis*), and bois d'arc (*Maclura pomifera*). Table 4-1 lists all tree species encountered within this forest.

Table 4-1. List of tree species found in the Ray Roberts Greenbelt.

Common Name	**Scientific Name**
Box elder	*Acer negundo*
Chittamwood	*Bumelia lanuginosa*
Pecan	*Carya illinoensis*
Sugar hackberry	*Celtis laevigata*
Netleaf hackberry	*Celtis reticulata*
Rough-leaf dogwood	*Cornus drummondii*
Hawthorn	*Crataegus* spp.
Common persimmon	*Diospyros virginiana*
Green ash	*Fraxinus pennsylvanica*
Honey locust	*Gleditsia triacanthos*
Black walnut	*Juglans nigra*
Eastern red cedar	*Juniperus virginiana*
Bois d'arc	*Maclura pomifera*
Red mulberry	*Morus rubra*
American sycamore	*Platanus occidentalis*
Eastern cottonwood	*Populus deltoides*

Bur oak	*Quercus macrocarpa*
Shumard oak	*Quercus shumardii*
Post oak	*Quercus stellata*
Blackjack oak	*Quercus marilandica*
Black willow	*Salix nigra*
Eve's necklace	*Sophora affinis*
Winged elm	*Ulmus alata*
American elm	*Ulmus americana*
Cedar elm	*Ulmus crassifolia*
Slippery elm	*Ulmus rubra*

Table 4-2 shows the importance values of each tree species found within the sampling plots. Hackberry and green ash dominate this forest with respect to basal area, density, and frequency in the forest. The forest is dominated by hackberry, green ash, cedar elm, and American elm; hackberry had an importance value of 34.94%, while green ash had an importance value of 19.75%. Cedar elm had an importance value of 8.82%, and American elm had an importance value of 5.25%. No other species had importance values higher than 5%. Table 4-3 shows the total basal area, number of trees per hectare, and frequency of plot occurrence for each tree species. Snags are an important component of this forest, with an overall importance value of 11.23% and a density of 37 standing dead trees per hectare. These results indicate that the forest may be classified as a hackberry-elm-ash forest type (cf. Nixon 1986).

Table 4-2. Importance values of sampled tree species.

Species	**Relative Dominance**	**Relative Density**	**Relative Frequency**	**Importance Value**
Hackberry	50.43	30.77	23.62	**34.94**
Green ash	28.02	16.67	14.57	**19.75**
Snags	7.07	12.05	14.57	**11.23**
Cedar elm	7.93	10.00	8.54	**8.82**
American elm	1.82	5.90	8.04	**5.25**

Pecan	1.30	4.36	3.52	**3.06**
Box Elder	0.64	3.59	4.52	**2.92**
Cottonwood	1.46	3.08	4.02	**2.85**
Red Mulberry	0.14	2.56	4.02	**2.24**
Bur oak	0.57	1.79	3.52	**1.96**
Slippery elm	0.30	2.31	2.51	**1.71**
Bois d'arc	0.18	2.05	2.51	**1.58**
Black willow	0.06	1.54	1.01	**0.87**
Honey locust	0.02	1.03	1.51	**0.85**
Sycamore	0.04	0.51	0.50	**0.35**
Post oak	0.00	0.51	0.50	**0.34**
Shumard oak	0.02	0.26	0.50	**0.26**
Chittamwood	0.01	0.26	0.50	**0.25**
Black walnut	0.00	0.26	0.50	**0.25**
Hawthorn	0.00	0.26	0.50	**0.25**
Blackjack oak	0.00	0.26	0.50	**0.25**
Sum	100	100	100	100

Table 4-3. Summary results of forest composition survey based on plot analysis.

Species	**Dominance (m^2/ha)**	**Density (trees/ha)**	**Frequency (# plots, n=62)**
Hackberry	653.3	94	47
Green ash	363.1	51	29
Snags	91.6	37	29
Cedar elm	102.7	31	17
American elm	23.6	18	16
Pecan	16.8	13	7
Box elder	8.3	11	9
Cottonwood	18.9	9	8
Red mulberry	1.8	8	8
Bur oak	7.3	6	7
Slippery elm	3.9	7	5
Bois d'arc	2.3	6	5
Black willow	0.8	5	2
Honey locust	0.3	3	3
American sycamore	0.5	2	1
Post oak	0.0	2	1
Shumard oak	0.2	1	1
Chittamwood	0.1	1	1
Black walnut	0.0	1	1
Hawthorn	0.0	1	1

Blackjack oak	0.0	1	1
Sum	1295.6	306	

Plot-by-plot analysis of forest characteristics shows a slightly patchy forest with respect to several phytosociological attributes. Tree richness is not as patchy as other attributes, partially due to the relatively small number of tree species in the forest as a whole; the highest species richness appears at plots 15, 27, 34, 43, 49, 55, and 58, with 5 species in each. The lowest tree species richness is 1 at plots 14, 19, and 45. On average, each plot had 3 tree species (mean and median were both found to be 3 species).

Both overall and snag dominance and density are patchy, seemingly due to the extrapolation of plot (100 m^2) values to hectare values, but actually due to the plot attributes themselves (as each value was extrapolated equally, the relative difference remains the same). Overall dominance is greater than 100 m^2/ha in many plots, showing a fairly high stem basal area across the forest. Dominance reaches a maximum of 222 m^2/ha at plot 36, and a minimum of 1 m^2/ha at plot 14. Average dominance for all sixty-two plots is 63 m^2/ha (median = 51 m^2/ha). Overall density reaches a maximum of 1300 stems per hectare at plot 55, and a minimum of 100 at plot 14. On average, density is approximately 629 trees/ha (median = 600 trees/ha). With respect to snags, average dominance equals just 0.07 m^2/ha (median = 0 m^2/ha); the highest value was found in plot 52, with a dominance value of 0.96 m^2/ha. Many plots had the minimum value of 0 m^2/ha; these plots did not contain snags. Average snag density is 76 snags per hectare (median = 0 snags/ha), with a maximum of 600 snags/ha at plots 49 and 55, and a minimum of 0 m^2/ha, found in the many plots that did not contain snags.

Compared with the phytosociological characteristics noted above, the canopy characteristics—including the number of layers, the percent canopy coverage, and the foliage height diversity (FHD) index—at each plot were somewhat more homogeneous (means and medians were identical for each plot). Maximum canopy layers at any given plot were 6 at plot 55. The minimum was 3 canopy layers; these values occurred at many different plots. On average, the number of canopy layers for all plots was 5. Canopy coverage varied from a maximum of 95% at plots 2 and 14, to a minimum of 35% at plot 57 (which contains a treefall gap in the canopy). Average canopy coverage was 75% across the Greenbelt forest. Foliage height diversity equaled 0.42 on average across the forest, with a maximum of 0.61 at plot 55 and a minimum of 0.20 at plot 45.

Four plots were classified as old growth: 7, 22, 25, and 37. The majority of the forest is classified as within the understory reinitiation phase of succession; this stage is often either mature forest or transitional old growth, depending on species composition as well as stand age and structural conditions (Oliver and Larson 1990). Complexity index values within the forest averaged 6.44 (median = 4.72), with a maximum of 22.91 at one old growth plot (plot 25) and a minimum of 0.003 at plot 14. No old growth plot had a complexity index value of less than the average; the lowest old growth complexity index value was 6.77 at plot 37.

Habitat Suitability Index (HSI) Results

The descriptive statistics for the HSI results are found in Table 4-4; full HSI variables and values for each plot are found in the appendix. For the Barred Owl (BROW) model, HSI values ranged from 0 to 1, with a mean value of 0.64 (median =

0.77). For the Pileated Woodpecker (PIWO) model, there were a range of HSI values from 0 to 0.76, with a mean value of 0.1 (median = 0). For the Hairy Woodpecker (HAWO) model, HSI values ranged from 0 to 0.95, with a mean value of 0.65 (median = 0.75).

Table 4-4. Descriptive statistics for Barred Owl (BROW), Pileated Woodpecker (PIWO), and Hairy Woodpecker (HAWO) HSI data.

	BROW	**PIWO**	**HAWO**
Mean	0.636	0.100	0.653
Standard Error	0.0426	0.0233	0.0380
Median	0.7746	0	0.7528
Mode	0	0	0.85
Minimum	0	0	0
Maximum	1.0	0.7550	0.95
Range	1.0	0.7550	0.95
Variance	0.1127	0.033637	0.0896
Standard Deviation	0.3357	0.183403	0.2992
Skewness	-1.0157	1.9765	-1.1177
Kurtosis	-0.2856	3.4865	0.0748

The maximum HSI value of 1.0 for the Barred Owl occurred at three stations (stations 5, 37, and 51) spread apart nearly the length of the Greenbelt. The minimum value of 0.00 occurred at several stations across the Greenbelt, including its occurrence in both patch and corridor areas. The patterns of HSI values for Pileated Woodpecker were similar, with maximums of 0.85 (station 62), 0.75 (station 61), and 0.72 (station 7) occurring at opposite ends of the Greenbelt. Most PIWO HSI values were much lower than these, when not at 0—the minimum, which occurred at most stations—values hovered in the vicinity of 0.20. These values were similar across both patch and corridors classes. Hairy Woodpecker HSI values were heterogeneous as well, with a maximum of 0.95 occurring at 11 stations throughout the length of the Greenbelt, including both patch and corridor forests. The minimum of 0.0 occurred at six stations spread along the Greenbelt, also occurring in both patch and corridor forests.

Landscape Analysis Results

The Ray Roberts Greenbelt and the adjacent landscape were analyzed to characterize the proportion of six landcover classes—agriculture, developed, forest, rangeland, shrubland, and water—within four different landscape analysis window sizes: 100 m radius, 500 m radius, 1000 m radius, and 2000 m radius from each point count station. This section discusses the results of this analysis, first, of the distance measures that may affect bird populations, second, of the overall landscape as the window size changes, and third, of each individual landcover class.

Distance Measures

The width of the riparian forest within the Greenbelt varied from a minimum of 50 m (station 2) to a maximum of 685 m (station 62). Distance to the nearest edge from each sampling station varied from a minimum of 10 m (stations) to a maximum of 330 m (station). Distance to interior forest varied from 0 m (all patch plots) to 1295 m (station 1). The descriptive statistics for each distance measure is found in Table 4-5.

Table 4-5. Descriptive Statistics for Landscape Distance Measures.

	Width	**Distance to Edge**	**Distance to Interior Forest**
Mean	230.4	88.55	254.35
Standard Error	22.00	10.12	43.78
Median	167.5	57.5	70

Mode	90	45	0
Minimum	50	10	0
Maximum	685	330	1295
Range	635	320	1295
Variance	30016	6347.04	118821.71
Standard Deviation	173.25	79.6683	344.7053
Skewness	1.1710	1.4480	1.3578
Kurtosis	0.4502	1.4632	0.7976

Landscape Characterization With Changes in Window Size

Each point count station was located within the riparian forest of the Greenbelt, so as might be expected, the primary forest class within the 100 meter class was forest. In narrow sections of the forest (corridors), other landcover classes became more prevalent in the smaller window sizes, though as window size increased, this effect was somewhat alleviated by the inclusion of nearby adjacent large patches of forest. Forest was the major landcover class at every window size, with an average of 55% of the landscape across all window sizes (grand mean), followed by agriculture with an average of 28%. Rangeland, shrubland, development, and water followed well behind the classes of forest and agriculture, with overall averages of 9%, 4%, 3%, and 1%, respectively. Each class is discussed individually in the next section of this chapter. The summary statistics for each window size are listed in Table 4-6 and are diagrammed in Figures 4-1 through 4-4.

Table 4-6. Summary Statistics of Window Sizes by Landscape Class.

Landcover Class	**Window Size (m)**	**Mean**	**Minimum**	**Maximum**	**Standard Deviation**
Forest	**100**	83%	26%	100%	0.182
	500	53%	13%	91%	0.200
	1000	43%	10%	68%	0.155
	2000	40%	20%	59%	0.107

Agriculture	**100**	9%	0%	54%	0.154
	500	31%	0%	85%	0.258
	1000	37%	0%	83%	0.254
	2000	34%	9%	63%	0.171
Rangeland	**100**	2%	0%	16%	0.037
	500	9%	0%	47%	0.130
	1000	11%	0%	32%	0.111
	2000	14%	5%	27%	0.074
Development	**100**	1%	0%	17%	0.027
	500	2%	0%	14%	0.033
	1000	4%	0%	18%	0.043
	2000	6%	1%	10%	0.027
Shrubland	**100**	4%	0%	26%	0.055
	500	4%	0%	17%	0.039
	1000	4%	0%	11%	0.026
	2000	5%	3%	8%	0.015
Water	**100**	1%	0%	14%	0.025
	500	1%	0%	2%	0.006
	1000	1%	0%	8%	0.011
	2000	2%	0%	24%	0.047

The only two classes that changed dramatically with changes in window size were forest and agriculture; all other classes showed slight increases in percent of area as window size increased. Forest declined quickly from a high of 83% at the 100 m window to a low of 40% within the 2000 m window size category. Agriculture climbed from a average low of 9% within 100 meters of the point, to a peak of 37% at 1000 meters. These two results correspond with field truthing of the landscape; as the distance away from the Greenbelt—and the riparian forest at its core—increases, the percent of forest across the landscape decreases dramatically. Agriculture peaks in the near vicinity of the Greenbelt due to higher surface and ground water availability; at further distances—2000 m and beyond—rangeland becomes gradually more important as readily available sources of water become more scarce.

Figure 4-1. Landcover Proportions in the 100 Meter Window.

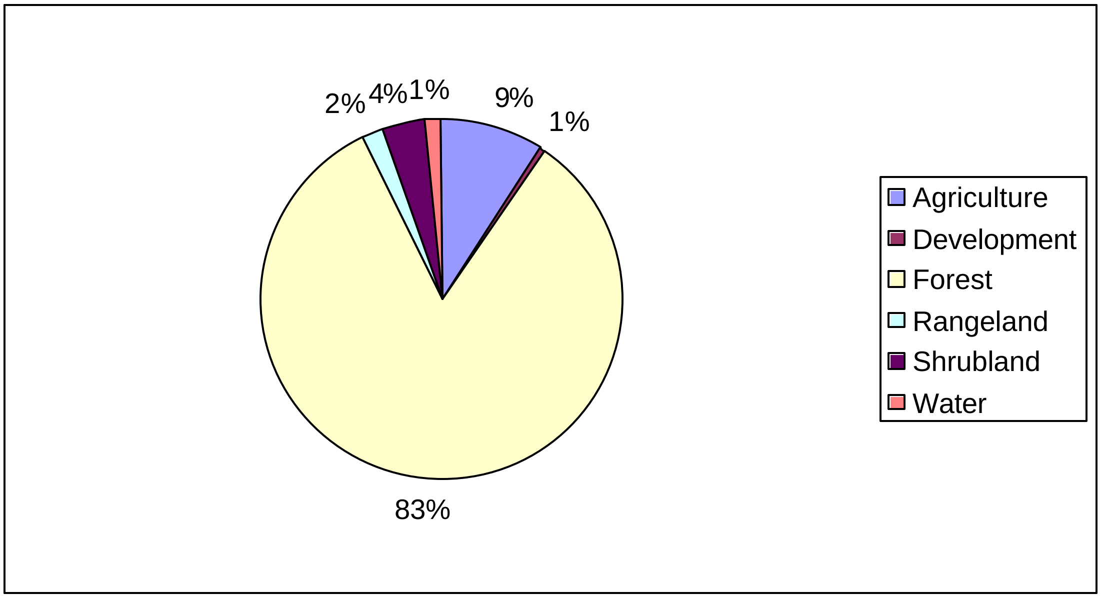


Figure 4-2. Landcover Proportions in the 500 Meter Window.

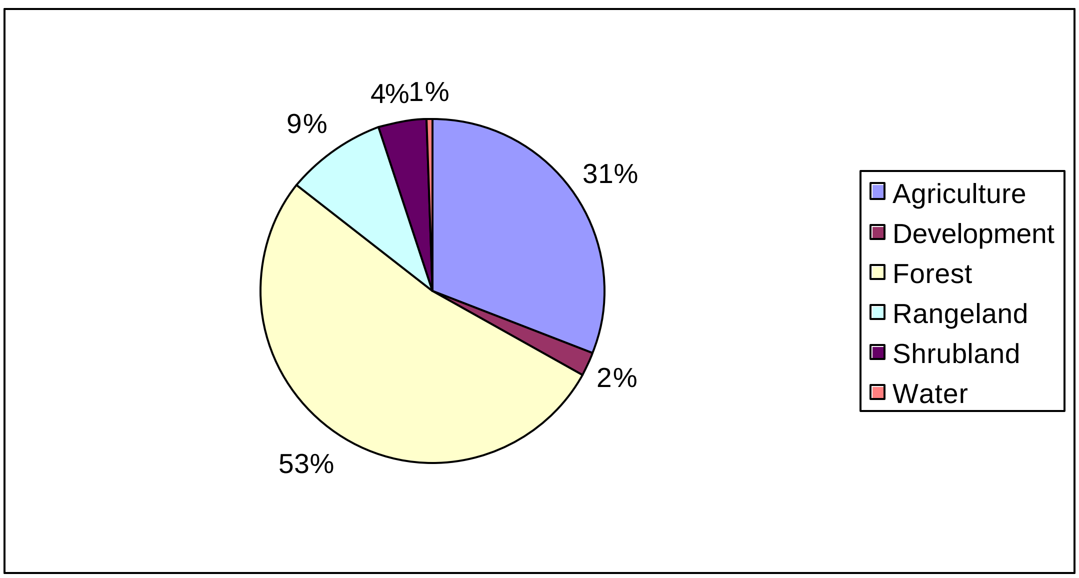


Figure 4-3. Landcover Proportions in the 1000 Meter Window.

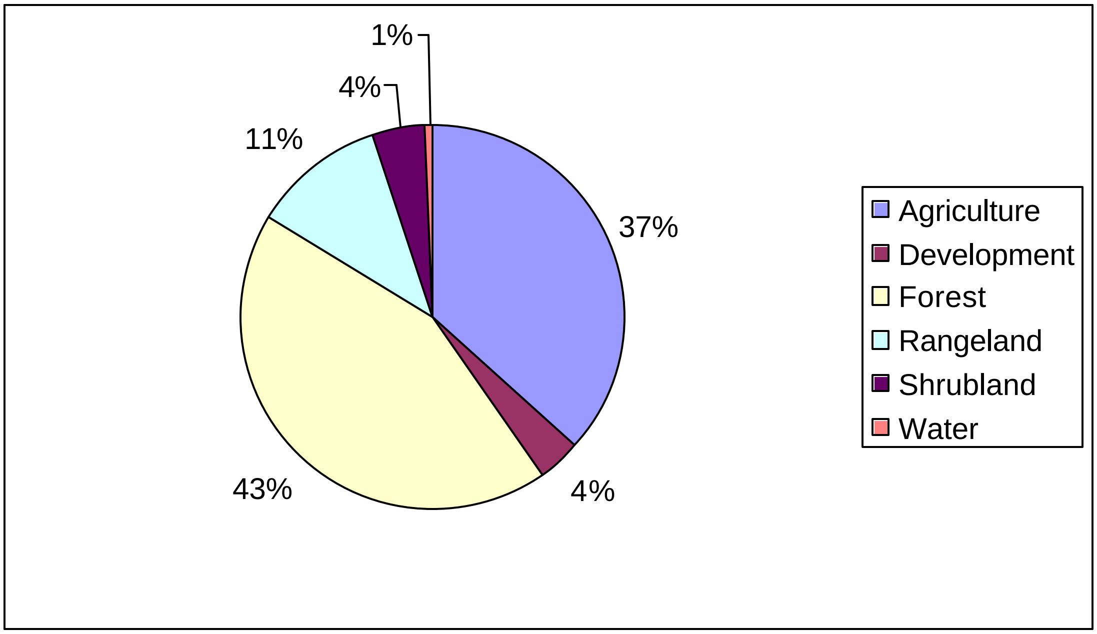
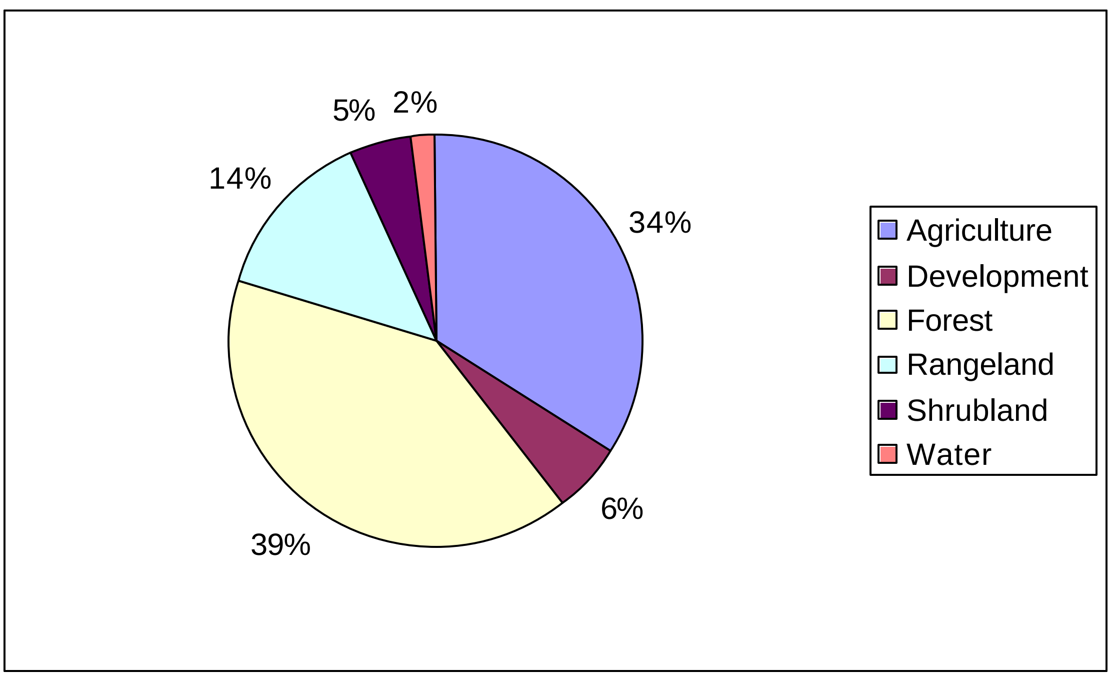


Figure 4-4. Landcover Proportions in the 2000 Meter Window.



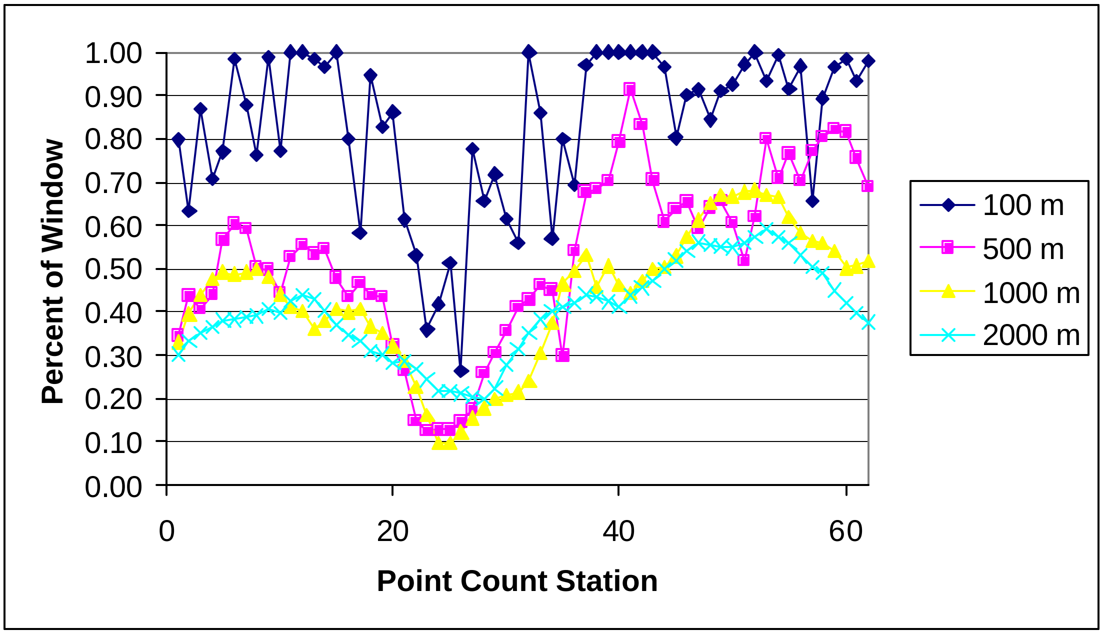
Landscape Characterization by Landcover Class

The six landcover classes are discussed successively in order of overall landscape dominance. Each class' figure shows percent of landscape within each window size at each point. The points are listed on the x-axis, from left to right, from point count station 1 at the north end of the Greenbelt at FM 455, to point count station 62 at the south end of the Greenbelt at US 380. The predominant landcover classes—forest and agriculture—were compared across window sizes for significant differences in their proportion of each window size. The other landcover classes, with make up a small proportion of each window in all size classes, were not compared.

Forest Landcover

Of primary importance to this study is the extent of forest within the study area. The extent of percent forest within each landscape window varied from a minimum of 10% in the 500 meter class (stations 24 and 25) to a maximum of 100% in the 100 meter class (stations 11, 12, 15, 32, 38-43, and 52). On average, the forest landcover comprised 83% of the landscape within 100 meters of the point count station, 53% of the landscape was forest in the 500 meter class, 43% in the 1000 meter class, and 40% in the 2000 meter class. The trends of forest landcover within two kilometers of each point count station in the Greenbelt are shown in Figure 4-5.

Figure 4-5. Comparisons of Forest Landcover by Window Size Along the Greenbelt.

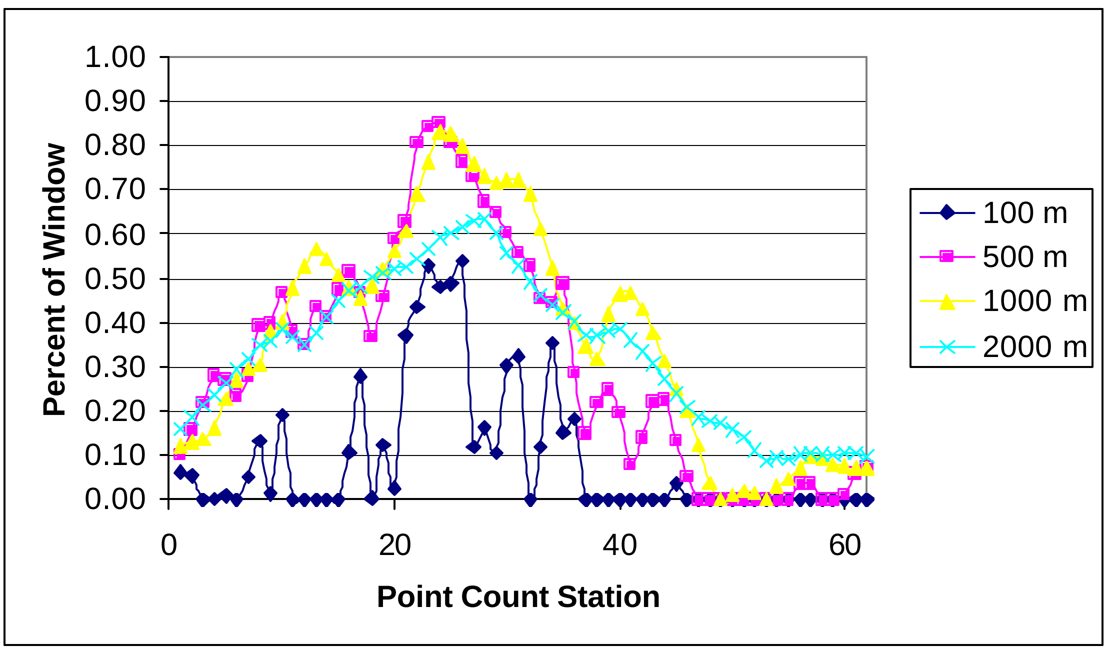


There was an overall negative spike in forest proportion between point count stations 16 and 36; otherwise, the proportion of forest in all window size classes remained fairly high. A Kruskal-Wallis ANOVA of the differences of forest landcover proportion by window size found a strongly significant difference ($p < 0.0001$). The 100 m window size contained a significantly higher proportion of forest than the other window sizes. The 500 m window contained a significantly lesser proportion of forest than the 100 m size, but was still significantly higher than the 1000 m and 2000 m window size classes. There was no significant difference between forest proportions in the 1000 m and 2000 m window sizes.

Agriculture Landcover

The second largest proportion of landcover in the Greenbelt region of Denton County is agriculture. The extent of percent agriculture within each landscape window varied from a minimum of 0% in the 100, 500, and 1000 meter classes (many stations) to a maximum of 85% in the 500 meter class (station 24). On average, the agricultural landcover comprised 9% of the landscape within 100 meters of the point count station, 31% of the landscape in the 500 meter class, 37% in the 1000 meter class, and 34% in the 2000 meter class.

Figure 4-6. Comparisons of Agriculture Landcover by Window Size Along the Greenbelt.



There was an overall spike in agriculture proportion evident in all window sizes that was maximized between point count stations 16 and 36; the proportion of agriculture in all window size classes generally climbed from station 1 to 24, and declined thereafter, all but disappearing at the south end of the Greenbelt around station 46 (Figure 4-6). A Kruskal-Wallis ANOVA of the differences of agriculture landcover proportion by window size found a strongly significant difference ($p < 0.0001$). The 100 m window size contained a significantly lower proportion of agriculture than the other window sizes. There was no significant difference between agricultural landcover proportions in the 500 m, 1000 m, and 2000 m window sizes.

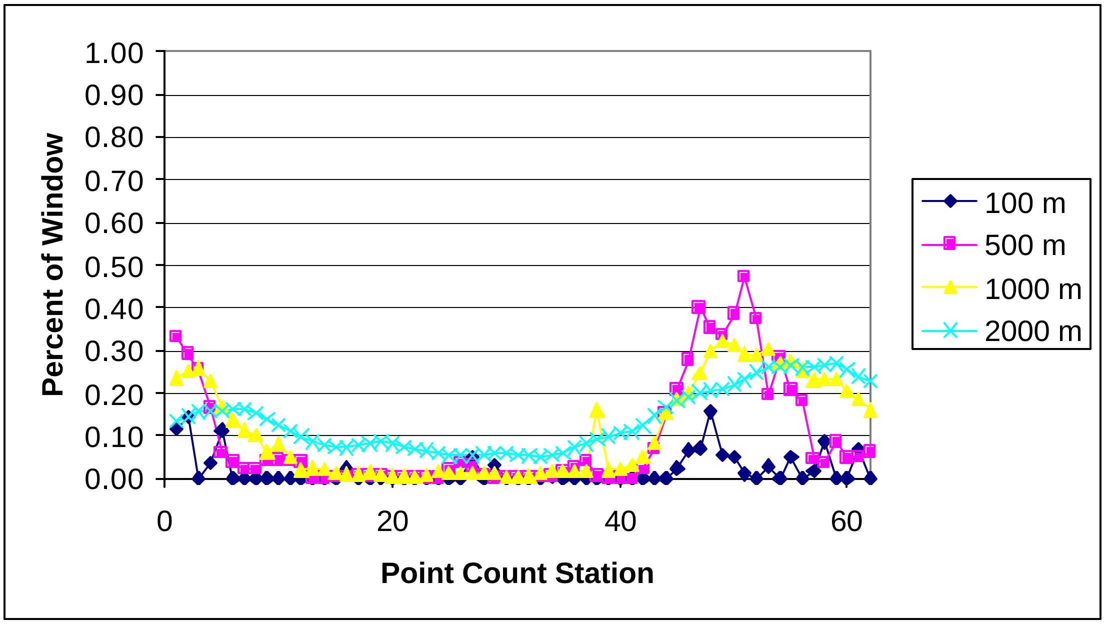
Rangeland Landcover

Rangeland—an important landcover class in Denton County—was not common in the Greenbelt area, as this landcover is not common in the bottomlands of major regional streams and rivers. Moving further from the Greenbelt, particularly to the west, this landcover begins to dominate the landscape. Within the study area, the extent of percent rangeland within each landscape window varied from a minimum of 0% in the 100, 500, and 1000 meter classes (several stations) to a maximum of 47% in the 500 meter class (station 51). On average, the rangeland landcover comprised just 2% of the landscape within 100 meters of the point count station, 9% of the landscape in the 500 meter class, 11% in the 1000 meter class, and 14% in the 2000 meter class.

There was a spike in the rangeland landcover class between stations 44 and 56, which was particularly evident in the 500 m window size. This peak is the result of old pastures reverting to range and shrublands on the west side of the Elm Fork near Hartlee Field and Collins Roads. Another smaller peak occurred near the north end of the Greenbelt, declining from stations 1 through 5. This peak occurs along the edge of the

Denton county rangelands, where the Elm Fork bottomlands are at their narrowest in the Greenbelt, below the Ray Roberts Dam. Figure 4-7 shows these trends.

Figure 4-7. Comparisons of Rangeland Landcover by Window Size Along the Greenbelt.

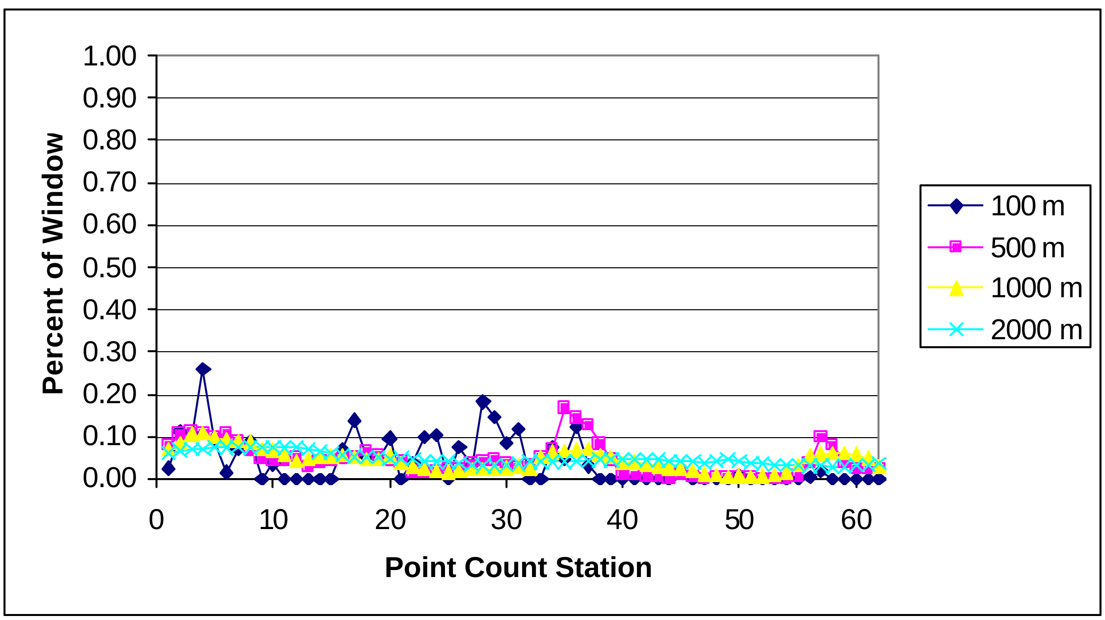


Shrubland Landcover

Shrubland is a minor component of the Elm Fork bottomlands and the surrounding landscape. Some of the old pastures and fields alongside the Elm Fork, once used for grazing or farming, are reverting slowly to forest. Some fields remain in grass and forbs (and are thus classified as rangeland), and some contain shrubs and small, early successional trees such as winged elm or hackberry (shrubland). The extent of percent shrubland within each landscape window varied from a minimum of 0% in the 100, 500, and 1000 meter classes (many stations) to a maximum of 26% in the 100 meter class (station 4). On average, the shrubland landcover comprised 4% of the landscape within 100, 500, and 1000 meters of the point count station, and 5% in the 2000 meter class.

Mimicking slightly the agricultural landcover class, shrublands had a section between stations 16 and 37 where the 100 meter class contained a higher than average proportion of shrubland, even though the peak occurred at station 4. This section between stations 16 and 37 is dominated largely by agriculture, and the proportion of shrubland is higher probably due to the large decline of forest. The peak at point 4 occurs near a large former clearing in the woods alongside the Elm Fork, where small trees have established the beginnings of a future forest. These trends in shrubland proportion can be seen in Figure 4-8.

Figure 4-8. Comparisons of Shrubland Landcover by Window Size Along the Greenbelt.

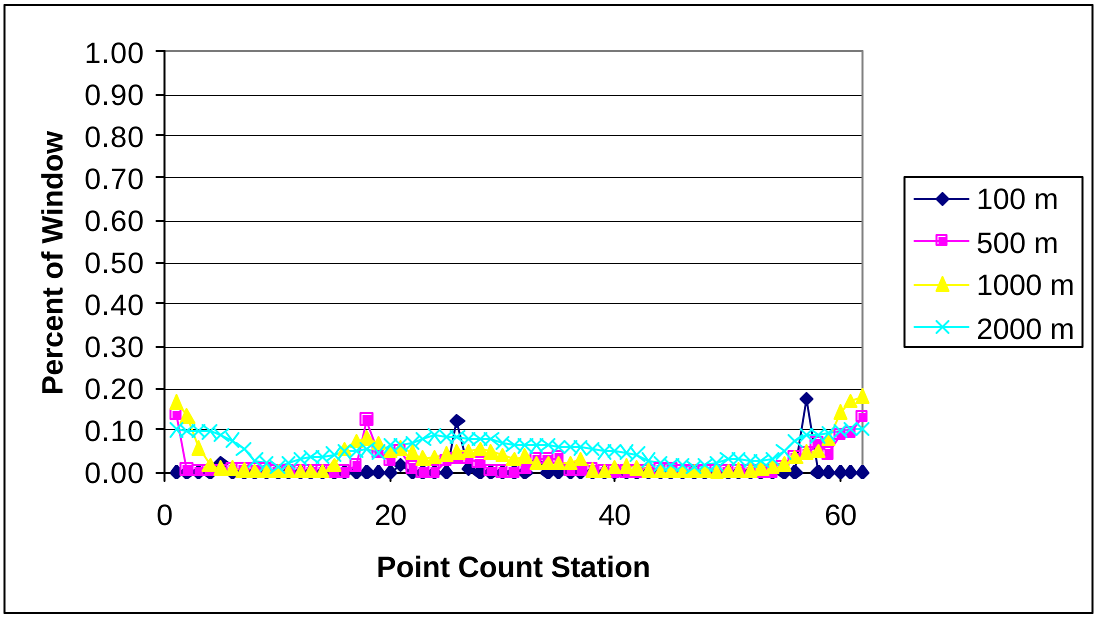


Development Landcover

Although one mid-sized city and one small town occur and around the Ray Roberts Greenbelt area (Denton and Aubrey, respectively), the proportion of developed area is fairly small within 2 kilometers of the point count stations. The extent of percent development within each landscape window varied from a minimum of 0% at many stations in all classes except for the 2000 meter class, to a maximum of 18% in the 1000 meter class (station 62). On average, the developed area of the landscape comprised only 1% of the landscape within 100 meters of the point count station, 2% in the 500 meter class, 4% in the 1000 meter class, and 6% in the 2000 meter class.

Figure 4-9 shows the proportion of developed land in the Greenbelt by window size class. Small spikes can be seen at points 1 and 18 in the 500 meter class, 26 and 57 in the 100 meter class, and at the ends in the majority of the window size classes (including the peak at the southern-most station, number 62). The peaks at each end include two of the three major roads in the study area, and station 26, near the middle of the Greenbelt, includes the third: FM 526, US 380, and FM 428, respectively. The peak at station 57 is due to the railroad running adjacent to the station, and the peak at station 18 includes a small region to the east of the Greenbelt dominated by low density housing.

Figure 4-9. Comparisons of Development Landcover by Window Size Along the Greenbelt.

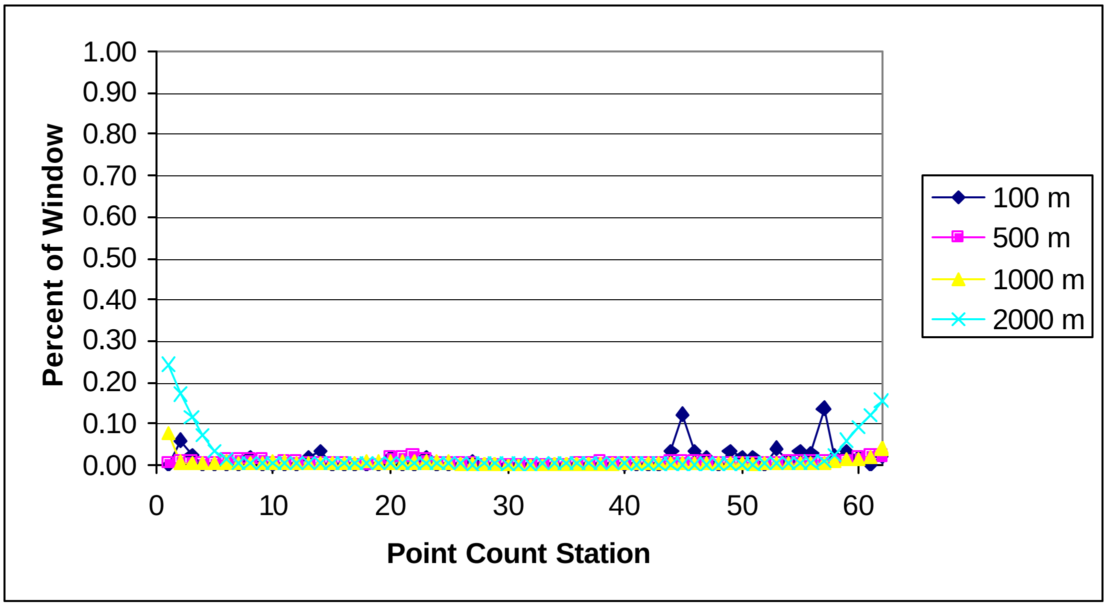


Water Landcover

Water was a minor part of the landscape with the exception of the plots near Lake Ray Roberts at the north end of the Greenbelt and Lewisville Lake at the south end of the Greenbelt. The extent of percent water within each landscape window varied from a minimum of 0% in all window size classes to a maximum of 24% in the 2000 meter class (station 1). On average, the water landcover class comprised only 1% of the landscape within 100, 500, and 1000 meters of the point count station, and 2% in the 2000 meter class.

Each end of the Greenbelt is framed by the two of the largest lakes in Denton County; the highest level of water landcover proportion at station 1 includes part of Lake Ray Roberts. Lake Lewisville is nearly a kilometer from station 62, so its presence is not really felt until viewed from the 2000 meter window. Two peaks occur in the 100 meter size class, at stations 45 and 57, which are due to wide sections of the Elm Fork near these point count stations. Figure 4-10 shows the proportion of water along the Greenbelt.

Figure 4-10. Comparisons of Water Landcover by Window Size Along the Greenbelt.



Discussion

The results of the forest analysis indicate that the forest is dominated by hackberry and green ash, and is likely to remain so well into the future. These species are able to tolerate relatively prolonged periods of inundation and are shade tolerant, attributes that have helped them survive and propagate in the closed canopy and in the frequently flooded environment beside the Elm Fork. Hackberry, green ash, and cedar elm occurred throughout most of the size classes (except for the very large ones, where large green ash trees were somewhat common and large hackberries were rare); this evidence of recruitment indicates that these species are replacing themselves and remaining as the “climax” community. The extreme size (and likely old age) of many individual trees within the forest indicates that conditions for their growth have existed for at least 150-250 years; however, the forest could be many centuries older, and some trees were estimated to be 300 years old (Barry and Kroll 1997, 1999).

The presence of numerous oak, pecan, and black walnut seedlings, paired with the sizable amount of mature bur and Shumard oaks located in the forest, may indicate a maturation of the floodplain soils underlying the forest, a condition that might lead to the oak-hickory community that is often found in old growth bottomland hardwood stands. The hypothetical movement of this forest to such a community is an event that would occur over hundreds of years and be subject to several factors including extent and duration of hydroperiods (flooding, rain, etc.). The presence of Lake Ray Roberts upstream will eliminate the flood cycles that have contributed so much to the current structure of the site; without the flood events which were so common, the water table underlying the forest should stabilize. Indication that this is already happening comes from the black walnuts, which are found in drier soils than hackberry, cedar elm, and green ash. The current distribution of bur oak, with large trees located on drier river-front sites and numerous seedlings readily apparent throughout the forest, also points to a changing water table, as bur oaks cannot withstand prolonged periods of inundation. Without the competitive advantage provided by past flood events, the structure of this forest may change from a hackberry-elm-ash forest to one dominated by a combination of bur and Shumard oaks and black walnuts, which are representative of classic old-growth and late successional bottomland hardwood forests (Hodges 1997).

Overall, these findings are consistent with trends in bottomland forest ecology and succession as noted by Nixon (1986), Nixon et al. (1990), Hodges (1997), and Kellison & Young (1997). Based on descriptive forest classification systems, the forest as a whole may be classified as transitional old-growth (Oliver and Larson 1990). Several sections of the forest were in the stand initiation stage, no doubt due to clearing prior to the acquisition of the land by the Corps of Engineers. Several smaller stands within the forest may be classified as true old-growth, based on species composition, age/size classes, and stand structural features (Barry and Kroll 1999).

The habitat for HSI model species evaluated for this study varied considerably within the Greenbelt forest, reflecting to some extent the differences in forest phytosociology and to a greater extent the differences within and among each species' more influential model variables. The Pileated Woodpecker depends upon an abundance of large snags to fulfill its life history requirements; areas that contained a large number of big snags were few and far between, likely due to the relatively fast decomposition rates in the humid environment of the bottomland forest. Without such large snags, habitat suitability for Pileated Woodpeckers declined dramatically; this occurred at most stations throughout the Greenbelt, where suitability was at or near zero. Hairy Woodpecker and Barred Owl habitat suitability was spread more evenly across the Greenbelt, as each species' model does not depend upon one particular variable to the same extent as the Pileated Woodpecker model. Suitable habitat for these species occurred throughout the Greenbelt.

The forest and agricultural landcover classes dominate the landscape of the Ray Roberts Greenbelt and the surrounding lands. Although other landcover classes dominate nearby—water to the north and south, development to the southwest, and rangeland to the west—within the bottomlands of the Elm Fork, the remnant forest and the fertile bottomland soils set the stage for the prevailing landcover types. The window size classes changed the proportion of landcover types within their viewsheds, which were fairly variable in the 100 and 500 meter classes, but that variation decreased as size increased at or above 1000 meters. Thus, in low-order bottomland landscapes and other riparian forests regions comparable to north central Texas, at least a 1000 meter window size is probably necessary to encompass the landscape variation surrounding the riverside forests.

The relationships between the forest habitat, the Greenbelt landscape, and the breeding bird community are discussed in successive chapters.

CHAPTER 5

1999 AND 2000 BREEDING BIRD SURVEYS

1999 Results

A total of 634 individual birds of 28 species were detected during sampling of the 1999 breeding season. An average of 7 species were detected at each station, with a maximum of 11 (stations 11, 13, and 37) and a minimum of 1 (station 60). An average of 10 individuals were detected at each station, with a maximum density of 19 (station 11) and a minimum density of 1 (station 60). Basic summary statistics of avian species richness and abundance during the 1999 breeding season are included in Table 5-1.

Table 5-1. Summary statistics for avian species richness and abundance during the 1999 breeding season.

	Richness	**Abundance**
Mean	6.97	10.24
Standard Error	0.247	0.421
Median	7	10
Mode	7	9
Minimum	1	1
Maximum	11	19
Range	10	18
Variance	3.769	11.006
Standard Deviation	1.942	3.318
Skewness	-0.286	0.318
Kurtosis	0.753	0.958

Northern Cardinal, Carolina Wren, and Carolina Chickadee were the most abundant species detected, with total abundances of 117 (18%), 97 (15%), and 80 (13%), respectively. These three species were distributed widely throughout the Greenbelt, occurring at 55 (89%), 54 (87%), and 48 (77%) stations, respectively. Single individuals of several species were detected at only one station each: Belted Kingfisher (station 61), Barred Owl (station 54), Great Blue Heron (station 6), Great Egret (station 52), and Hairy Woodpecker (station 37).

Seven forest interior species were detected in the 1999 breeding season, including Pileated Woodpecker, Hairy Woodpecker, Barred Owl, Northern Parula, Prothonotary Warbler, Red-eyed Vireo, and Red-shouldered Hawk. Their abundances and frequencies of occurrence are listed in Table 5-2.

Table 5-2. Abundance and Frequency of Forest Interior Bird Species During the 1999 Breeding Season.

Species	**Abundance** (Proportional Abundance)	**Frequency** (Percent Plot Occurrence)
Red-eyed Vireo	24 (4%)	21 (34%)
Northern Parula	9 (1%)	7 (11%)
Red-shouldered Hawk	7 (1%)	6 (10%)
Prothonotary Warbler	6 (1%)	4 (6%)
Pileated Woodpecker	3 (<1%)	3 (5%)
Barred Owl	1 (<1%)	1 (2%)
Hairy Woodpecker	1 (<1%)	1 (2%)

These forest interior birds were detected throughout the Greenbelt, having an average density of approximately 0.7 individuals per station, representing an average of 0.7 species at each point. Basic summary statistics of forest obligate bird species richness and abundance during the 1999 breeding season are included in Table 5-3. Figures 5-1 and 5-2 present the species richness and density for each station along the Greenbelt for 1999.

Table 5-3. Summary Statistics for Forest Interior Bird Species Richness and Abundance During the 1999 Breeding Season.

	Richness	**Abundance**
Mean	0.66	0.69
Standard Error	0.108	0.116
Median	0	0
Mode	0	0
Minimum	0	0
Maximum	3	4
Range	3	4
Variance	0.719	0.839
Standard Deviation	0.848	0.916
Skewness	1.222	1.451
Kurtosis	0.886	2.097

Figure 5-1. Forest Interior Species Richness in the 1999 Breeding Season.

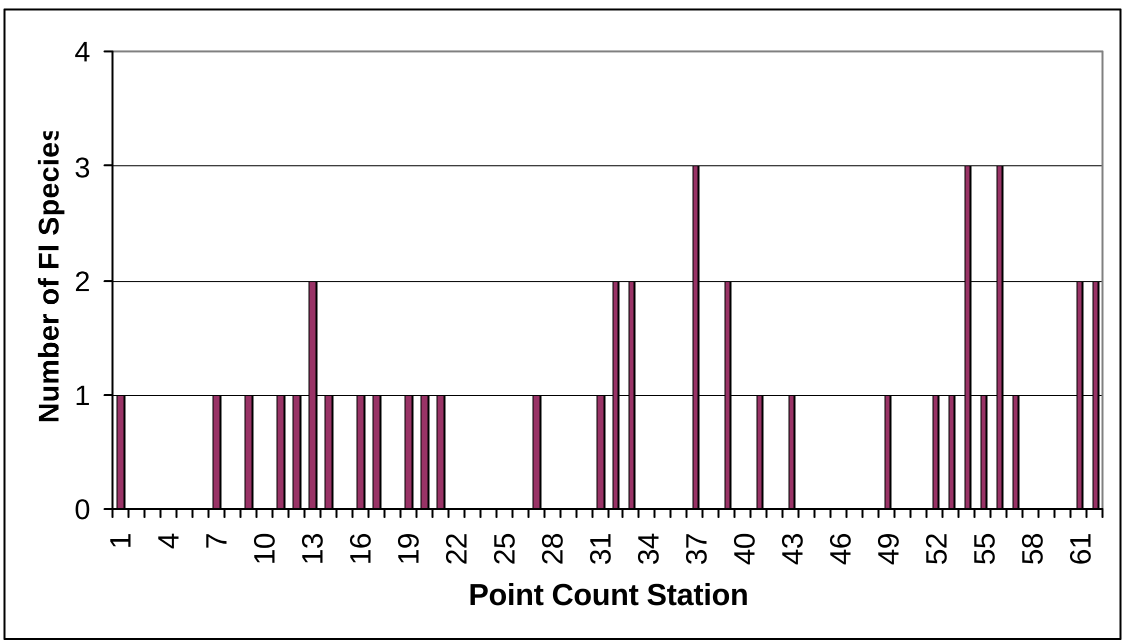
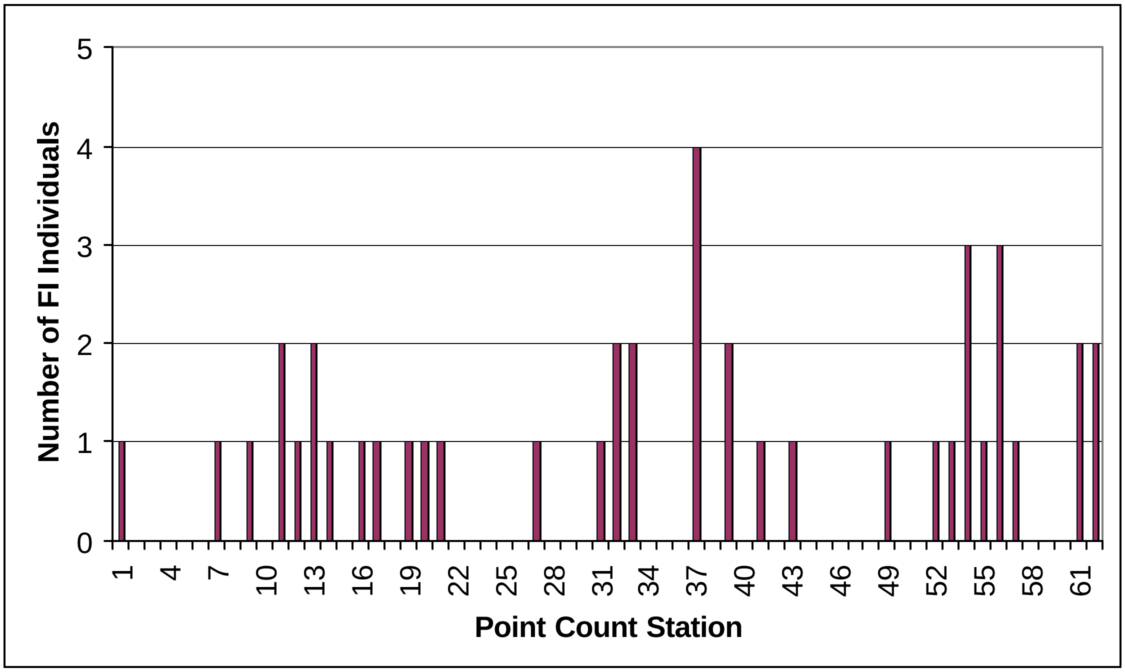


Figure 5-2. Forest Interior Species Abundance in the 1999 Breeding Season.



Fourteen species were detected in the 1999 breeding season that are considered area-sensitive, that is, their probability of occurrence increases with the proportion of forest within 2 km of the sample point (Robbins et al. 1989). These species include Blue-gray Gnatcatcher, Eastern Tufted Titmouse, Red-bellied Woodpecker, Red-eyed Vireo, Yellow-billed Cuckoo, American Crow, Northern Parula, Great-crested Flycatcher, Red-shouldered Hawk, Prothonotary Warbler, Blue Jay, Pileated Woodpecker, Eastern Wood-Pewee, and Hairy Woodpecker. The abundances and frequencies of occurrence of these area-sensitive species are listed in Table 5-4.

Table 5-4. Abundance and Frequency of Area Sensitive Bird Species During the 1999 Breeding Season.

Species	**Abundance** (Proportional Abundance)	**Frequency** (Percent Plot Occurrence)
Blue-gray Gnatcatcher	38 (6%)	29 (47%)
Eastern Tufted Titmouse	32 (5%)	23 (37%)
Red-bellied Woodpecker	27 (4%)	22 (35%)
Red-eyed Vireo	24 (4%)	21 (34%)
Yellow-billed Cuckoo	18 (3%)	15 (24%)
American Crow	14 (2%)	8 (13%)
Northern Parula	9 (1%)	7 (11%)
Great-crested Flycatcher	8 (1%)	7 (11%)
Red-shouldered Hawk	7 (1%)	6 (10%)
Prothonotary Warbler	6 (1%)	4 (6%)
Blue Jay	3 (<1%)	3 (5%)
Pileated Woodpecker	3 (<1%)	3 (5%)
Eastern Wood-Pewee	3 (<1%)	3 (5%)
Hairy Woodpecker	1 (<1%)	1 (2%)

Nest parasites such as the Brown-headed Cowbird and nest predators such as the American Crow, Blue Jay and the Common Grackle were all detected, with abundances of 12 (2%), 14 (2%), 3 (<1%), and 2 (<1%). Each species occurred at 11 (18%), 8 (13%), 3 (5%), 2 (3%) stations, respectively.

2000 Results

A total of 830 individual birds of 34 species were detected during sampling of the 2000 breeding season. An average of 8 species were detected at each station, with a maximum of 13 (stations 48 and 61) and a minimum of 3 (station 33). An average of 13 individuals were detected at each station, with a maximum density of 21 (stations 7 and 40) and a minimum density of 6 (stations 26 and 33). Basic summary statistics of avian species richness and abundance during the 2000 breeding season are included in Table 5-5.

Table 5-5. Summary Statistics for Avian Species Richness and Abundance During the 2000 Breeding Season.

	Richness	**Abundance**
Mean	7.90	13.39
Standard Error	0.257	0.462
Median	8	14
Mode	7	12
Minimum	3	6
Maximum	13	21
Range	10	15
Variance	4.089	13.258
Standard Deviation	2.022	3.641
Skewness	0.345	-0.122
Kurtosis	0.405	-0.489

Northern Cardinal, Carolina Wren, and Carolina Chickadee were the most abundant species detected in this season as well, with total abundances of 189 (23%), 130 (16%), and 88 (11%), respectively. These three species were distributed widely throughout the Greenbelt, occurring at 61 (98%), 60 (97%), and 45 (73%) stations, respectively. Several species were detected only once: Dickcissel (station 48), Great Egret (station 56), Eastern Bluebird (station 21), Eastern Pheobe (station 26), Mockingbird (station 19), Red-shouldered Hawk (station 6), Ruby-throated Hummingbird (station 16), and Warbling Vireo (station 34).

Eight forest interior species were detected in 2000, including Pileated Woodpecker, Hairy Woodpecker, Northern Parula, Prothonotary Warbler, Red-eyed

Vireo, Red-shouldered Hawk, Ruby-crowned Kinglet, and Summer Tanager. Their abundances and frequencies of occurrence are listed in Table 5-6.

Table 5-6. Abundance and Frequency of Forest Interior Bird Species During the 2000 Breeding Season.

Species	**Abundance** (Proportional Abundance)	**Frequency** (Percent Plot Occurrence)
Northern Parula	24 (3%)	18 (29%)
Red-eyed Vireo	21 (3%)	20 (32%)
Prothonotary Warbler	14 (2%)	11 (18%)
Hairy Woodpecker	5 (1%)	5 (8%)
Summer Tanager	3 (<1%)	2 (3%)
Pileated Woodpecker	2 (<1%)	2 (3%)
Ruby-crowned Kinglet	2 (<1%)	2 (3%)
Red-shouldered Hawk	1 (<1%)	1 (2%)

These forest interior birds were detected throughout the Greenbelt in 2000, having an average density of approximately 1.1 individuals per station, representing an average of 1 species at each point. Basic summary statistics of forest obligate bird species richness and abundance during the 2000 breeding season are included in Table 5-7. Figures 5-3 and 5-4 present the species richness and density for each station along the Greenbelt for 2000.

Table 5-7. Summary Statistics for Forest Interior Bird Species Richness and Density During the 2000 Breeding Season.

	Richness	**Density**
Mean	0.97	1.15
Standard Error	0.100	0.134
Median	1	1
Mode	1	1
Minimum	0	0
Maximum	3	4
Range	3	4
Variance	0.622	1.110
Standard Deviation	0.789	1.053
Skewness	0.472	0.918
Kurtosis	-0.182	0.366

Figure 5-3. Forest Interior Species Richness in the 2000 Breeding Season.

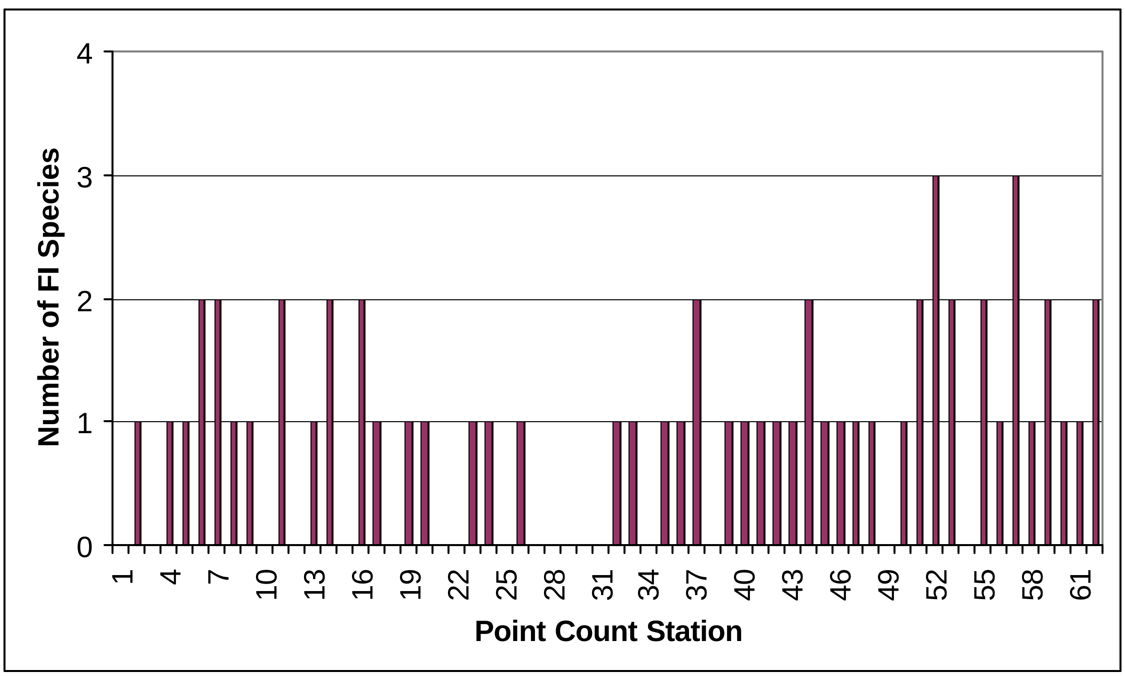
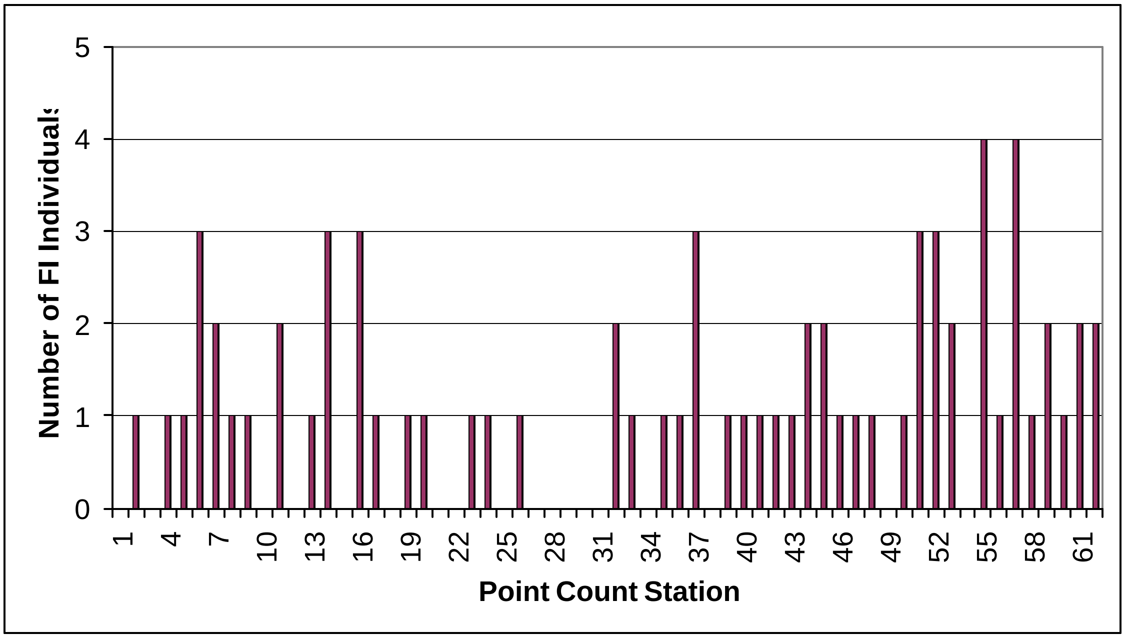


Figure 5-4. Forest Interior Species Abundance in the 2000 Breeding Season.



Fifteen area-sensitive species were detected in 2000, including Blue-gray Gnatcatcher, Red-bellied Woodpecker, Eastern Tufted Titmouse, Yellow-billed Cuckoo, Northern Parula, Red-eyed Vireo, Prothonotary Warbler, Eastern Wood-Pewee, Great-crested Flycatcher, Hairy Woodpecker, Blue Jay, American Crow, Summer Tanager, Pileated Woodpecker, and Red-shouldered Hawk. The abundances and frequencies of occurrence of these area-sensitive species are listed in Table 5-8.

Table 5-8. Abundance and Frequency of Area Sensitive Bird Species During the 2000 Breeding Season.

Species	**Abundance** (Proportional Abundance)	**Frequency** (Percent Plot Occurrence)
Blue-gray Gnatcatcher	45 (5%)	34 (55%)
Red-bellied Woodpecker	44 (5%)	34 (55%)
Eastern Tufted Titmouse	44 (5%)	26 (42%)

Yellow-billed Cuckoo	29 (3%)	22 (35%)
Northern Parula	24 (3%)	18 (29%)
Red-eyed Vireo	21 (3%)	20 (32%)
Prothonotary Warbler	15 (2%)	12 (19%)
Eastern Wood-Pewee	12 (1%)	11 (18%)
Great-crested Flycatcher	6 (1%)	4 (6%)
Hairy Woodpecker	5 (1%)	5 (8%)
Blue Jay	5 (1%)	4 (6%)
American Crow	5 (1%)	2 (3%)
Summer Tanager	3 (<1%)	2 (3%)
Pileated Woodpecker	2 (<1%)	2 (3%)
Red-shouldered Hawk	1 (<1%)	1 (2%)

Nest parasites, predators, and competitors, such as the Brown-headed Cowbird, American Crow, Blue Jay, and European Starling were all detected during the 2000 breeding season, with total abundances of 16 (2%), 5 (1%), 5 (1%), and 3 (<1%). Each species occurred at 13 (21%), 2 (3%), 4 (6%), 2 (3%) stations, respectively.

Discussion

The Ray Roberts Greenbelt represents some of the largest tracts of minimally-disturbed habitat in Denton County; as such, the habitat supports a relatively complete and diverse avian community. Over 100 different species have been seen in the Greenbelt during all parts of the year, not all of which breed there (the focus of this study). Some notable species seen during migration and winter seasons include Bald Eagle, Osprey, Sharp-shinned Hawk, Prairie Falcon, Northern Harrier, Wild Turkey, Yellow-bellied Sapsucker, Hermit Thrush, Great-horned Owl, Barn Owl, American Goldfinch, and Yellow-rumped Warbler (Hoffman, unpublished data).

The extent of the riparian forest along the Elm Fork of the Trinity River has decreased significantly since Anglo colonization. As a result, some populations of breeding native bird species seem to be quite small, primarily those that depend upon large tracts of intact forest. In particular, the Pileated Woodpecker individuals detected year-round in the Greenbelt represent the only known population in the Dallas-Ft. Worth Metropolitan Area, and have been the only individuals detected in this area since 1986 (Steigman, personal communication).

Great Blue Heron was detected only once each breeding season, in spite of the existence of two known rookeries within the Greenbelt. In 1999, this species was detected at station 6; in 2000 Great Blue Heron was detected at station 5. Both of these points are near one of the known rookeries; the other rookery was outside of the sampling area.

Barred Owl was heard hooting fairly frequently in the mornings near the center of the Greenbelt, in the forests on both sides of FM 428. It was detected within 50 meters of the point at station 54 in 1999, and not within that distance in 2000. However, it was detected outside of the 50 m range both years at several stations.

The Warbling Vireo detected at station 34 in 2000 was probably a late migrant passing through north Texas on its way north.

A total of 37 species were detected within 50 meters of each point count station during the breeding seasons of this two year study, nine of which are forest interior species (24%), and 15 of which are forest area sensitive species (41%). Table 5-9 lists the overall species list and their classification status (forest area sensitive and/or forest interior) with respect to this study. Only one exotic species was detected in this same sampling area, the European Starling. The nine forest interior species detected during this study were Pileated Woodpecker, Hairy Woodpecker, Barred Owl, Northern Parula, Prothonotary Warbler, Red-eyed Vireo, Red-shouldered Hawk, Ruby-crowned Kinglet, and Summer Tanager. Barred Owl was only sampled during 1999, and Ruby-crowned Kinglet, and Summer Tanager were only detected during 2000. The remaining species were sampled in both years. Maximum richness and abundance of forest interior species are shown for each station along the Greenbelt in Figures 5-5 and 5-6.

Table 5-9. Overall Species List and Forest Classifications for the 1999 and 2000 Breeding Seasons Combined.

Common Name	**Scientific Name**	**Forest Area Sensitive**	**Forest Interior**
American Crow	*Corvus brachyrhynchos*	*	
Barred Owl	*Strix varia*		*
Belted Kingfisher	*Ceryle alcyon*		
Blue Jay	*Cyanocitta cristata*	*	
Blue-gray Gnatcatcher	*Polioptila caerulea*	*	
Brown-headed Cowbird	*Molothrus ater*		
Carolina Chickadee	*Parus carolinensis*		
Carolina Wren	*Thryothorus ludovicianus*		
Common Grackle	*Quiscalus quiacula*		
Dicksissel	*Spiza americana*		
Downy Woodpecker	*Picoides pubescens*		
Eastern Bluebird	*Sialia sialis*		
Eastern Pheobe	*Sayornis phoebe*		
Eastern Tufted Titmouse	*Parus bicolor*	*	
Eastern Wood Peewee	*Contopus virens*	*	
Great Blue Heron	*Ardea herodias*		
Great Crested Flycatcher	*Myiarchus crinitus*	*	
Great Egret	*Casmerodius albus*		
Hairy Woodpecker	*Picoides villosus*	*	*
Indigo Bunting	*Passerina cyanea*		
Mockingbird	*Mimus polyglottos*		
Northern Cardinal	*Cardinalis cardinalis*		
Northern Parula	*Parula americana*	*	*
Painted Bunting	*Passerina ciris*		
Pileated Woodpecker	*Dryocopus pileatus*	*	*
Prothonotary Warbler	*Protonotaria citrea*	*	*

Red-bellied Woodpecker	*Melanerpes carolinus*	*	
Red-eyed Vireo	*Vireo olivaceus*	*	*
Red-shouldered Hawk	*Buteo lineatus*	*	*
Ruby-crowned Kinglet	*Regulus calendula*		*
Ruby-throated Hummingbird	*Archilochus colubris*		
European Starling	*Sturnus vulgaris*		
Summer Tanager	*Piranga rubra*	*	*
Warbling Vireo	*Vireo gilvus*		
White-eyed Vireo	*Vireo griseus*		
Wood Duck	*Aix sponsa*		
Yellow-billed Cuckoo	*Coccyzus americanus*	*	

Figure 5-5. Maximum Forest Interior Species Richness by Point Count Station.

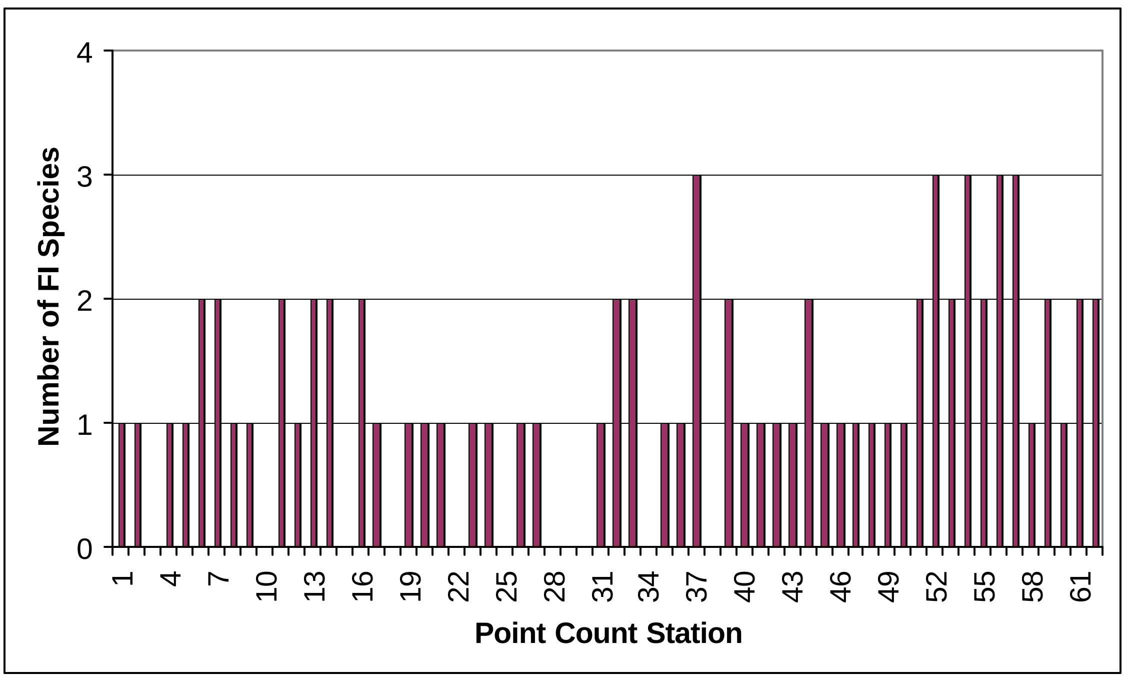
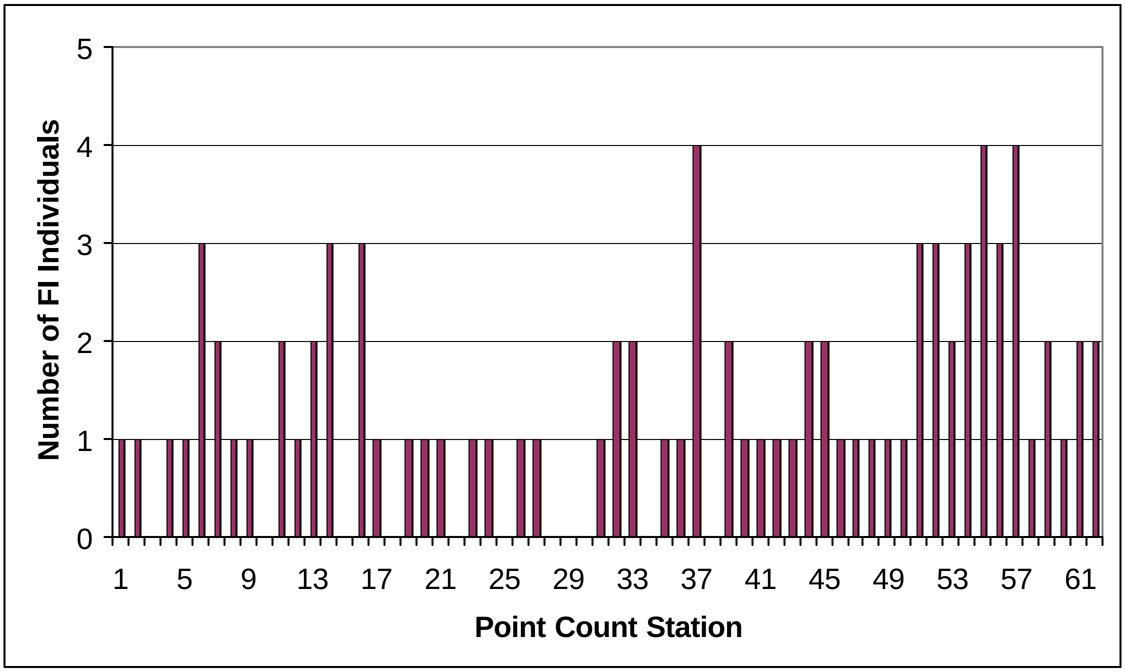


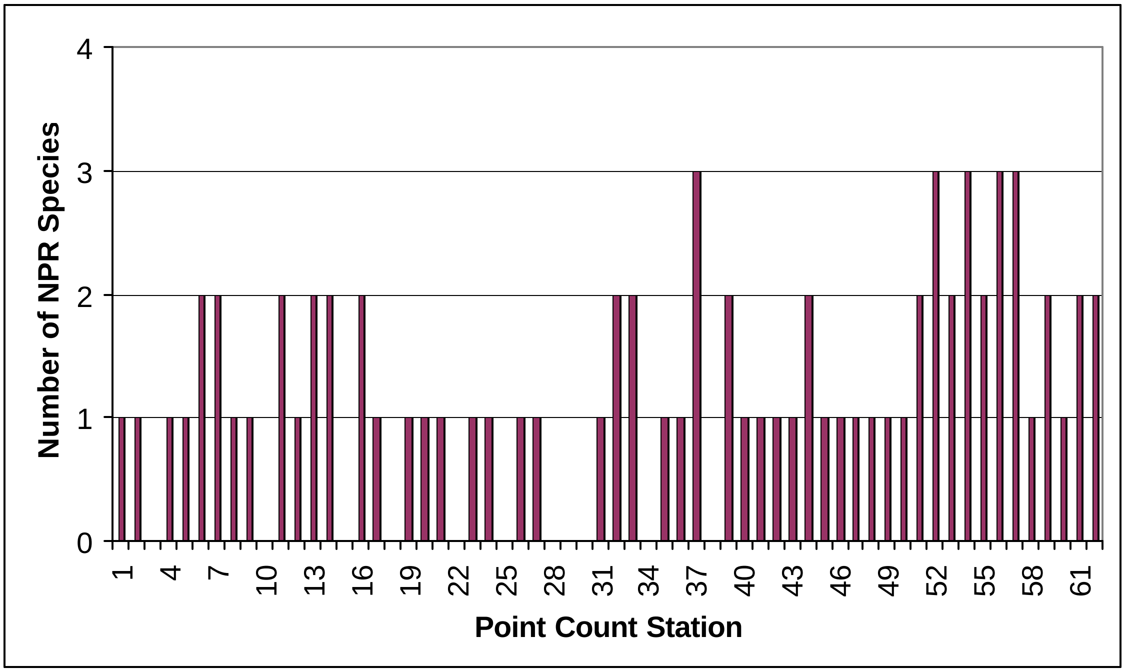
Figure 5-6. Maximum Forest Interior Species Abundance by Point Count Station.



The fifteen forest area sensitive species detected during this study were Blue-gray Gnatcatcher, Red-bellied Woodpecker, Eastern Tufted Titmouse, Yellow-billed Cuckoo, Northern Parula, Red-eyed Vireo, Prothonotary Warbler, Eastern Wood-Pewee, Great-crested Flycatcher, Hairy Woodpecker, Blue Jay, American Crow, Summer Tanager, Pileated Woodpecker, and Red-shouldered Hawk. All species except Summer Tanager were detected both years; the Summer Tanager was only detected in 2000.

Five species were detected during this study that are nest predators, parasites, or competitors (NPR species): Brown-headed Cowbird, American Crow, Blue Jay, European Starling, and Common Grackle. Mortality in bird species is often highest in the juvenile stage, prior to reaching reproductive age; thus, these species represent a significant intra-class mortality factor that can affect population dynamics. The Brown-headed Cowbird is a particular problem in this respect, especially with the breeding success of many Neotropical migrant species (Robinson 1995). Figure 5-7 shows the presence and abundance of these species at each point count station in the Greenbelt for both years (combined). The figure shows a fairly widespread occurrence of at least one NPR individual across most of the Greenbelt; with peaks of NPR density of 3 individuals at stations 37, 52, 54, 56, and 57. Each of these stations are located at or near the edges of patch forests, which indicates a possible affinity for NPR stations to edge habitats near large patches. This implies that NPR species may be benefiting from the presence of the variety of host or victim species that use these types of habitats. Indeed, a weak but significant correlation was found between maximum forest interior species density and maximum NPR species density (R = 0.2681, $p = 0.0352$), as well as for overall species density and NPR density in 1999 (R = 0.3518, p = 0. 0051) and 2000 (R = 0.4197, $p = 0.0007$). There was not such a relationship between NPR density and forest interior species density in 1999, though there was one in 2000 (R = 0.3029, $p = 0.0167$). These weak but significant correlations indicate that the NRP species are benefiting from the nesting birds of the Greenbelt, but are not primarily attached to these particular places in order to fulfill their life history requirements.

Figure 5-7. Nest Predator, Parasite, or Competitor Abundance by Point Count Station.



The relationships between the bird species classes that were detected during 1999 and 2000 breeding seasons and their habitats within and adjoining the Greenbelt are discussed in successive chapters.

CHAPTER 6

COMPARING AVIAN/HABITAT/LANDSCAPE DIFFERENCES IN CORRIDOR AND PATCH FORESTS

Forest Phytosociology

The forest of the Ray Roberts Greenbelt is somewhat homogenous in terms of species composition and importance values through the length of the Greenbelt. Overall, percent community similarity between the forest patches and forest corridors was 77%, and no significant differences were found in density or dominance of the forest between these two subclasses of the forest community. Individual plots—such as station 18, which is located where a finger of the Cross Timbers ecosystem protrudes into the Greenbelt—show some marked differences, but comparing plots located in patches and plots located in corridors shows no major difference. Importance values of the more common species overall (see Chapter 4)—green ash, hackberry, and cedar elm—were still high when separated into the subclasses of patch and corridor (Table 6-1). Hackberry and cedar elm importance values were twice as high in patches as they were in corridors, and green ash importance value was twice as high in corridor plots as it was in patch plots. With respect to wildlife benefits, snag importance was essentially identical between subclasses (patches = 10.27; corridors = 11.37).

Table 6-1. Importance values for tree species in patch and corridor plots.

Species	Patch	Corridor
Hackberry	41.12	31.31
Cedar elm	12.69	6.84
Green ash	12.19	23.74
Snag	10.27	11.37
Cottonwood	6.06	1.66
Box Elder	3.25	2.79
Pecan	2.40	3.37
Slippery elm	2.18	1.48
Red Mulberry	2.13	2.30
Bur oak	1.67	2.10
Bois d'arc	1.57	1.60
Black willow	1.33	0.65
Shumard oak	0.83	0.00
Honey locust	0.78	0.89
American elm	0.78	7.71
Hawthorn	0.78	0.00
Sycamore	0.00	0.53
Post oak	0.00	0.51
Chittamwood	0.00	0.38
Black walnut	0.00	0.38
Blackjack oak	0.00	0.38

Habitat Evaluation

The habitat of the Ray Roberts Greenbelt is remarkably homogenous; of the sixteen habitat variables measured at each plot, only the Barred Owl HSI results showed a significant difference between values in plots located in the larger patches and those located in the corridor sections. There were no significant differences between any HSI values in corridors and HSI values in patches except for the Barred Owl model ($p = 0.04$), where corridors plots had a significantly higher Barred Owl HSI value than did patch plots. Mean Barred Owl HSI value in patches was 0.554 (median = 0.671), whereas mean

HSI value in corridors was 0.673 (median = 0.775). Three corridor plots had Barred Owl habitat suitability index values of 1.0 (optimal habitat; stations 5, 37, and 51); the maximum Barred Owl HSI value in patches was 0.92 at one station (station 56). Fifteen plots in the corridor subclass had Barred Owl HSI values of greater than 0.90.

Metrics meant to quantify the structural habitat of a forest (as opposed to phytosociological composition), such as foliage height diversity, complexity index, percent canopy coverage, snag density and importance, and average dbh, as well as the HSI results (and the variables subsumed within the HSI equations) (see the Appendix for a full list of evaluated variables), were not significantly different between the patches and corridors of the Greenbelt.

Landscape Evaluation

The landscape of the Ray Roberts Greenbelt shows more differences between the patch and corridor subclasses than was found in the habitat and forest analyses. Within the 100 m window size, significant differences were found between corridor and patch subclass in percent landcover composition of agriculture ($p < 0.01$), forest ($p < 0.01$), rangeland ($p = 0.02$), and shrubland ($p < 0.01$). Within the 500 m window, the only significant difference was found in forest cover ($p < 0.01$). Within the 2000 m window, the only significant difference was also in forest cover ($p = 0.04$). No significant differences were found between corridor regions and patch regions in any landcover class in the 1000 m window size group. Basic statistics of the significant differences are found in Table 6-2.

Table 6-2. Basic statistics of significant differences between patch and corridor regions in percent landcover composition by window size.

Landcover (Window Size)	**Patch Mean** (Standard Deviation)	**Corridor Mean** (Standard Deviation)	**Patch Median**	**Corridor Median**
Agriculture (100 m)	0.00 (0.00)	0.13 (0.17)	0.00	0.05
Rangeland (100 m)	0.01 (0.02)	0.02 (0.04)	0.00	0.00
Shrubland (100 m)	0 (n/a)	0.06 (0.06)	0	0.03
Forest (100 m)	0.98 (0.02)	0.76 (0.18)	1.00	0.80
Forest (500 m)	0.66 (0.14)	0.47 (0.20)	0.69	0.45
Forest (2000 m)	0.44 (0.06)	0.39 (0.12)	0.43	0.38

Within the corridor sections, the width of the forest varied from a minimum of 50 m (station 2) to a maximum of 425 m (station 59). Station 59 was counted in the corridor class due to its proximity to the powerlines than transect the lower portion of the Greenbelt. The width of the forest at the patch stations varied from a minimum of 245 m (station 9) to a maximum of 685 m (station 62). Within the corridor sections, the distance to the edge of the forest varied from a minimum of 10 m (stations 4, 16 and 17) to a maximum of 90 m (stations 37, 44, and 59). The distance to the edge of the forest at the patch stations varied from a minimum of 105 m (station 12) to a maximum of 330 m (station 41). The distance to the nearest interior forest patch within the corridor sections varied from a minimum of 5 m (station 44) to a maximum of 1295 m (station 1). The distance to the nearest interior forest patch within the patch sections was, by definition, always zero. As might be expected (due to their relationship with the process of classifying the forest into patches and corridors), differences between patches and corridors with respect to these distance measures were highly significant ($p < 0.01$ for all measures).

Avian Communities

1999 Breeding Season

Within the corridor sections, 424 individuals of 26 species were detected within the corridors, and 211 individuals of 24 species were detected within the patch forests. The species detected in corridors and not in patches included Barred Owl, Eastern Phoebe, Great Blue Heron, and Hairy Woodpecker. Species only sampled within the interior forests included the Belted Kingfisher, Great Egret, and Pileated Woodpecker. The same three species—Northern Cardinal, Carolina Wren, and Carolina Chickadee—dominated the avian community in the corridors and patches as they did in the forest as a whole; their data are listed in Table 6-3.

Table 6-3. Abundance and Frequency of the Dominant Species in Patches and Corridors During the 1999 Breeding Season.

	Abundance		**Frequency**	
Species	**Patch** (n=211)	**Corridor** (n=424)	**Patch** (n=19)	**Corridor** (n=43)
Northern Cardinal	37 (18%)	80 (19%)	17 (89%)	38 (88%)
Carolina Wren	30 (14%)	67 (16%)	15 (79%)	39 (91%)
Carolina Chickadee	22 (10%)	58 (14%)	14 (74%)	34 (79%)

On average, 11.1 individuals of 7.3 species were found at each station in the patches, whereas 9.8 individuals of 6.8 species were found at corridor stations. The maximum richness for any one station was 11 in each class, and maximum density was 19 in the patch subclass and 15 in the corridor subclass. Richness and density were not significantly different between patches and corridors. A comparison of forest interior species found an average of 1.2 individuals of 1.1 species per station in the patches, and just 0.5 individuals of 0.5 species per station in the corridor sections. The differences in forest interior species richness and density between corridors and patches were significant ($p < 0.01$ for both). Shannon diversity in the patch forest stations (H' = 2.769) and the corridor forest stations (H' = 2.588) was significantly different ($p = 0.02$) as well. While diversity was higher in patches, the corridor avian community was more even. Percent similarity of the two overall avian communities was calculated to be 89%, while percent similarity of the forest-interior species communities comparing corridors and patches was only 58%. Average species richness, average density of individuals, Shannon diversity, and evenness for each set are presented in Table 6-4.

Table 6-4. Diversity Metrics of Patch and Corridor Avian Communities during the 1999 breeding season.

	Patches (n = 19)	Corridors (n = 43)
Average Richness (S)	7.3	6.8
Maximum S	11	11
Minimum S	1	3
Average Density (D)	11.1	9.9
Maximum D	19	15
Minimum D	1	4
Shannon Diversity (H')	2.769	2.588
H'_{MAX}	3.258	3.178
Evenness (J)	0.794	0.871

The community of forest interior species was similar comparing patches and corridors; Red-eyed Vireo was the most abundant and frequently seen bird species during the 1999 breeding season in both patches and corridors (Table 6-5). Red-eyed Vireo was more frequently seen in corridors than patches, and was more abundant in that subclass as well. These differences are not significant, however. Most forest interior species were not seen often in 1999, and their small sample size makes considerations of their habitat preferences difficult to make in the context of the Greenbelt. Pileated Woodpecker, known for its affinity for interior forest, was found only at patch stations in 1999.

Table 6-5. Abundance and Frequency of the Forest Interior Species in Patches and Corridors During the 1999 Breeding Season.

	Abundance		**Frequency**	
Species	**Patch** (n=24)	**Corridor** (n=27)	**Patch** (n=19)	**Corridor** (n=43)
Red-eyed Vireo	8 (33%)	16 (59%)	7 (37%)	14 (33%)
Northern Parula	3 (13%)	6 (22%)	3 (16%)	4 (9%)
Red-shouldered Hawk	5 (21%)	2 (7%)	4 (21%)	2 (5%)
Prothonotary Warbler	5 (21%)	1 (4%)	3 (16%)	1 (2%)
Pileated Woodpecker	3 (13%)	0	3 (16%)	0
Hairy Woodpecker	0	1 (4%)	0	1 (2%)
Barred Owl	0	1 (4%)	0	1 (4%)

Nest parasites and robbers were similar in frequency and abundance during the 1999 breeding season (Table 6-6). American Crow and Brown-headed Cowbird were the most common species detected. No significant differences existed between patches and communities for these species.

Table 6-6. Abundance and Frequency of the Nest Parasite/Robber Species in Patches and Corridors During the 1999 Breeding Season.

	Abundance		**Frequency**	
Species	**Patch** (n=14)	**Corridor** (n=17)	**Patch** (n=19)	**Corridor** (n=43)
American Crow	6 (43%)	8 (47%)	2 (11%)	6 (14%)
Brown-headed Cowbird	5 (36%)	7 (41%)	4 (21%)	7 (16%)
Blue Jay	2 (14%)	1 (6%)	2 (11%)	1 (2%)
Common Grackle	1 (7%)	1 (6%)	1 (5%)	1 (2%)

2000 Breeding Season

For the 2000 breeding season, 559 individuals of 31 species were detected within the corridors, and 271 individuals of 24 species were detected within the patch forests. The species detected in corridors and not in patches included Dicksissel, Eastern Bluebird, Eastern Phoebe, Great Blue Heron, Great Crested Flycatcher, Mockingbird, Red-shouldered Hawk, Ruby-throated Hummingbird, Summer Tanager, and Warbling Vireo. Species only sampled within the interior forests included the Great Egret, Ruby-crowned Kinglet, and Wood Duck. The same three species—Northern Cardinal, Carolina Wren, and Carolina Chickadee—dominated the avian community in the corridors and patches as they did in the forest as a whole; their data are listed in Table 6-7.

Table 6-7. Abundance and Frequency of the Dominant Species in Patches and Corridors During the 2000 Breeding Season.

	Abundance		**Frequency**	
Species	**Patch** (n=271)	**Corridor** (n=559)	**Patch** (n=19)	**Corridor** (n=43)
Northern Cardinal	58 (21%)	131 (23%)	19 (100%)	42 (98%)
Carolina Wren	43 (16%)	87 (16%)	18 (95%)	42 (98%)
Carolina Chickadee	31 (11%)	57 (10%)	16 (84%)	29 (67%)

Less differences were found in the 2000 breeding bird season data than were found in 1999. On average, 14.3 individuals of 8.3 species were found at each station in the patches, whereas 13.0 individuals of 7.7 species were found at corridor stations. The maximum richness and density for any one station was 13 and 21 in each class, respectively. As in 1999, richness and density were not significantly different between patches and corridors in 2000. A comparison of forest interior species found an average of 1.4 individuals of 1.2 species per station in the patches, and 1.0 individuals of 0.9 species per station in the corridor sections. The differences in forest interior species richness and density between corridors and patches were not significant in 2000. Shannon diversity in the patch forest stations (H' = 2.62) and the corridor forest stations (H' = 2.63) was not significantly different. Both subclassess had approximately the same evenness (~0.8). Percent similarity of the two overall avian communities was calculated to be 89%, as it was in 1999, and—unlike 1999—percent similarity of the forest-interior species communities comparing corridors and patches was nearly the same, at 82%. Average species richness, average density of individuals, Shannon diversity, and evenness for each set are presented in Table 6-8.

Table 6-8. Diversity Metrics of Patch and Corridor Avian Communities during the 2000 breeding season.

	Patches (n = 19)	**Corridors (n = 43)**
Average Richness (S)	8.3	7.7
Maximum S	5	3
Minimum S	13	13
Average Density (D)	14.3	13.0
Maximum D	7	6
Minimum D	21	21
Shannon Diversity (H')	2.621	2.626
H'_{MAX}	3.178	3.258
Evenness (J)	0.825	0.806

The community of forest interior species was similar; Northern Parula and Red-eyed Vireo were the most abundant and frequently seen birds during the 2000 breeding season in both patches and corridors (Table 6-9). Red-eyed Vireo was more frequently seen in patches and corridors, but their abundances were fairly similar in both subclasses (~30%). Prothonotary Warbler had a higher abundance in corridor sections than in patches, but was frequently seen and sampled in both at nearly the same percentage (~20%). Hairy Woodpecker, Pileated Woodpecker, Summer Tanager, Ruby-crowned Kinglet, and Red-shouldered Hawk were not seen often in 2000, and their small sample size makes considerations of their habitat preferences difficult to make in the context of the Greenbelt. Unlike 1999, Pileated Woodpecker was sampled at both corridor and patch stations, which suggests that the individual sampled in the corridor (at station 50) was using it for movement between patches.

Table 6-9. Abundance and Frequency of the Forest Interior Species in Patches and Corridors During the 2000 Breeding Season.

	Abundance		**Frequency**	
Species	**Patch** (n=29)	**Corridor** (n=44)	**Patch** (n=19)	**Corridor** (n=43)
Northern Parula	11 (38%)	13 (30%)	6 (32%)	12 (28%)
Red-eyed Vireo	8 (28%)	13 (30%)	8 (42%)	12 (28%)
Prothonotary Warbler	4 (14%)	11 (26%)	4 (21%)	8 (19%)
Hairy Woodpecker	3 (10%)	2 (5%)	3 (16%)	2 (5%)
Pileated Woodpecker	1 (3%)	1 (2%)	1 (5%)	1 (2%)
Summer Tanager	0	3 (7%)	0	2 (5%)
Ruby-crowned Kinglet	2 (7%)	0	1 (5%)	0
Red-shouldered Hawk	0	1 (2%)	0	1 (2%)

Nest parasites and robbers showed some small differences in the avian communities of the 2000 breeding season (Table 6-10). Specifically, Brown-headed Cowbird was much more frequently seen and had higher abundances in the corridor sections than the patch sections. However, this difference was not significant, due to the larger sample size of the corridor sections. The other species also did not show significant differences between frequency and abundances when contrasting patches and corridors.

Table 6-10. Abundance and Frequency of the Nest Parasite/Robber Species in Patches and Corridors During the 2000 Breeding Season.

	Abundance		**Frequency**	
Species	**Patch** (n=11)	**Corridor** (n=16)	**Patch** (n=19)	**Corridor** (n=43)
Brown-headed Cowbird	3 (27%)	13 (81%)	3 (16%)	10 (23%)
American Crow	4 (36%)	1 (6%)	1 (5%)	1 (2%)
Blue Jay	2 (18%)	1 (6%)	2 (11%)	1 (2%)
Starling	2 (18%)	1 (6%)	1 (5%)	1 (2%)

Discussion

The responses of avian communities and populations to environmental variables in space and time can be the result of inter- and intra-specific competition, physiological limitations, landscape factors, habitat factors, demographic dynamics, or random variation. These causes are often interrelated, with the strength of any particular influence varying with the species and its particular environmental context. A subset of potential variables influential in avian communities of the Ray Roberts Greenbelt were compared, with few differences to be found.

With respect to the forest phytosociological analysis: if the two forest subclasses (i.e. patch forest and corridor forests) were distinct forests, each would still be classified as hackberry-elm-ash forests; their community type is identical. The differences between the two subclasses, noted above, were ecologically trivial. In the analysis of corridor and patch similarity, the two forest subclasses showed approximately 75% similarity when the importance values of all tree types were included. This would seem to indicate that from a habitat perspective, little phytosociological difference exists between the areas designated as corridor and those designated as patch.

Similar results were found in the analysis of habitat data subdivided into the two subclasses of patch and corridor. Only one of the sixteen habitat metrics sampled or evaluated—the Barred Owl HSI value—showed any significant difference between patch plots and corridor plots. No other variables showed significant differences in habitat features. The factors that are responsible for the differences in Barred Owl habitat value relate primarily to the number and average size of the trees in and around the sampling stations; when there were no large trees, habitat value declined (was usually = 0) accordingly. Canopy closure was the other variable involved with calculating habitat value for the Barred Owl; this value did not influence the results as much as the forest size. Thus, the reasons for a slightly significant difference between patches and corridors are probably the result of the HSI formula itself, because the direct measures of forest habitat that are included within the Barred Owl model did not show significant differenes. This indicates that the Barred Owl HSI model should be modified to reflect local conditions before continued use in the Elm Fork bottomlands.

Taken together, the forest and habitat analyses suggest that the biological and structural composition of the Ray Roberts Greenbelt forest is fairly homogenous throughout its length, including in the comparisons between corridors and patches. These results indicate that it may be possible to maintain much of the habitat value present in larger patches along corridors connecting them. This supports the practice of providing corridors connecting larger patches of habitat, demonstrating that there is a continuation of habitat value from the patch to the corridor.

The landscape analysis found more variation than did the analysis of the forest and habitat of the Ray Roberts Greenbelt. Most differences were found in the 100 m window size, which would be expected based upon the small amount of land that is covered by this window size. These differences occurred in four of the six landcover classes (development and water did not show any significant differences). The exception was in the forest class, which had significant differences in its proportion of landcover between patches and corridors in all window sizes except at 1000 m. These differences reflect the state of the forest itself with respect to its subclass; almost by definition, a corridor forest region will naturally have a lower proportion of forest cover than will a patch forest region. The 100 m window size—where, as might be expected, the most variation occurred—might reveal patterns that exert a strong influence on local conditions in and around each station, and these differences may account for variations (if any) in avian communities.

The avian results are ambiguous. During the 1999 breeding season, significant differences were found between patches and corridors in species richness, density, and diversity; these differences were not found in 2000. No differences were found in the forest interior species and the nest parasite/robber species when contrasting patches and corridors. The reasons for the differences in the richness, density, and diversity results between 1999 and 2000 are not clear; the weather between the two years was similar, and one member of the sampling team was at every point count station in both years. If sampling only occurred in 2000, the conclusion might be drawn that the homogeneity of habitat is the primary influence on the avian community. If sampling only occurred in 1999, one might point to landscape factors as driving variables in the numeric composition (i.e. diversity metrics) of avian communities. Taken together, the homogeneity of the forest habitat and the differences in forest cover at most relevant scales (and the overall landscape at small scales) suggest that any differences seen in the avian community may be the result of landscape factors or of factors not under consideration by this study.

Overall, within the forest along the Elm Fork within the Ray Roberts Greenbelt, there are few differences that distinguish patches and corridors from each other. This suggests that the differences that do occur in avian communities between patches and corridors are influenced by a small set of variables or are affected by processes (e.g., demographic or stochastic) outside the scope of this research project. These possible relationships as were analyzed by this project are discussed in successive chapters.

CHAPTER 7

RELATIONSHIPS BETWEEN BREEDING BIRDS AND HABITAT/LANDSCAPE FACTORS

Overview

Birds are affected by a great range of environmental factors throughout their life; in terms of population dynamics, these factors are most important during the breeding season, as breeding season habitats provide the resources and context in which reproduction and fledging take place. While winter habitat factors are also important in population dynamics (as this is when resources for metabolic maintenance are most limited, which has significant implications for survival), the wide geographic range of winter habitats for the breeding residents of the Greenbelt (i.e., from South America to North Texas) precludes effective analysis. Therefore, this chapter presents the habitat and landscape factors that may influence the breeding bird community of the Ray Roberts Greenbelt during the breeding seasons of 1999 and 2000, and the strength to which these factors correlate with the breeding avian community of those years.

Whole Greenbelt Correlations

An interesting pattern emerges when exploring the relationships between breeding birds in the Greenbelt and the landscape and habitat features that provide their context: of the 416 correlations run for overall and forest interior species richness, only 13 correlations with habitat factors were significant ($p < 0.05$), while 72 correlations with landscape factors were significant. These correlations are separated by overall species richness and abundance, and forest interior species richness and abundance. Tables 7-1 and 7-2 present the correlations for landscape and habitat factors, respectively, for overall bird species richness or abundance. Forest interior species correlations with landscape and habitat factors are presented in Tables 7-3 and 7-4, respectively, which follow the discussion of Tables 7-1 and 7-2.

Table 7-1. Landscape Factors Correlated with Overall Species Richness or Abundance.

Correlation	**Spearman R**	***p*-level**
Overall Richness 1999		
Development (1000m)	-0.30	0.02
Overall Richness 2000		
Forest (2000m)	0.39	<0.01
Forest (1000m)	0.34	0.01
Forest (500m)	0.33	0.01
Forest (100m)	0.26	0.05
Distance to Nearest Edge	0.25	0.05
Agriculture (1000m)	-0.26	0.04
Distance to Interior Forest	-0.26	0.04
Development (500m)	-0.29	0.02
Development (2000m)	-0.32	0.01
Agriculture (500m)	-0.33	0.01
Agriculture (100m)	-0.38	<0.01
Overall Abundance 1999		
Distance to Nearest Edge	0.29	0.02
Shrubland (2000m)	0.26	0.04
Distance to Interior Forest	-0.30	0.02
Development (1000m)	-0.31	0.02
Overall Abundance 2000		
Forest (500m)	0.45	<0.01
Forest (2000m)	0.43	<0.01
Forest (1000m)	0.38	<0.01

Rangeland (2000m)	0.34	0.01
Distance to Nearest Edge	0.31	0.01
Forest (100m)	0.30	0.02
Forest Width	0.26	0.04
Agriculture (2000m)	-0.28	0.03
Agriculture (1000m)	-0.30	0.02
Development (2000m)	-0.31	0.02
Distance to Interior Forest	-0.35	0.01
Agriculture (500m)	-0.40	<0.01
Agriculture (100m)	-0.41	<0.01

Table 7-2. Habitat Factors Correlated with Overall Species Richness or Abundance

Correlation	**Spearman R**	***p*-level**
Overall Richness 1999		
Nest Parasite/Robber Richness	0.31	0.01
Nest Parasite/Robber Abundance	0.28	0.03
Overall Richness 2000		
Nest Parasite/Robber Richness	0.32	0.01
Nest Parasite/Robber Abundance	0.31	0.01
Overall Abundance 1999		
Nest Parasite/Robber Richness	0.38	<0.01
Nest Parasite/Robber Abundance	0.35	0.01
Number of Forest Canopy Layers	-0.30	0.02
Overall Abundance 2000		
Nest Parasite/Robber Abundance	0.42	<0.01
Nest Parasite/Robber Richness	0.41	<0.01

The strongest correlations for overall species richness and abundance were all around approximately R = 0.4 or R = –0.4, showing that relationships between the breeding bird communities and particular habitat or landscape factors are not very strong. With respect to landscape factors, 1999 showed few significant relationships with the avian community. The strongest of these—a negative relationship for development within 1000 m—was related to both avian richness (R = –0.3) and abundance (R = –0.31) at approximately the same strength. Agriculture within 100 m and 500 m showed some negative relationships with both richness (R = –0.38, –0.33) and abundance (R = –0.41, –0.4) in the 2000 breeding season; development and agriculture at further distances both showed some negative relationships as well. As might be expected, the strongest positive relationships between the avian community and landscape factors were with the percent of forest within all window size classes, with R values ranging between 0.3 (2000 abundance, forest 100 m) and 0.45 (2000 abundance, forest 500 m). Forest width and distance to nearest edge were significantly correlated with the overall avian community as well, but to a much lesser extent, with R values ranging between 0.25 (2000 richness, distance to edge) and 0.31 (2000 abundance, distance to edge). The 1999 breeding season showed few significant correlations, with 4 landscape factors related to avian abundance (development within 1000 m [R = –0.31], distance to interior forest [R = –0.3], distance to nearest edge [R = 0.29], and shrubland within 2000 m [R = 0.26]) and only 1 factor related to avian richness (development within 1000 m [R = –0.3]).

The majority of "habitat" factors that showed a relationship to the overall avian community in all years for both richness and abundance—nest parasites and robbers (such as the Brown–headed Cowbird)—are not habitat factors at all in a strict sense; instead, these factors are actually the "dependent" variables when compared to the rest of the avian community, as these birds are dependent upon nests of other species for parasitism or predation. Thus, the only habitat variable with a significant relationship to the overall avian community that might influence the community's distribution might be the number of canopy layers, which showed a correlation coefficient of R = –0.3 with overall abundance in the 1999 breeding season.

The patterns of correlations between landscape and habitat factors and forest interior species richness or abundance follow a similar pattern as the overall avian community. Tables 7-3 and 7-4 show the significant ($p < 0.05$) correlations between the forest interior avian community and landscape and habitat factors, respectively.

Table 7-3. Landscape Factors Correlated with Forest Interior Species Richness or Abundance.

Correlation	**Spearman R**	***p*-level**
Forest Interior Richness 1999		
Forest Width	0.48	<0.01
Distance to Forest Edge	0.37	<0.01
Forest (100m)	0.34	0.01
Agriculture (100m)	-0.26	0.04
Shrubland (100m)	-0.31	0.01
Distance to Interior Forest	-0.49	<0.01
Forest Interior Richness 2000		
Forest (1000m)	0.49	<0.01
Rangeland (2000m)	0.45	<0.01
Forest (500m)	0.44	<0.01
Forest (2000m)	0.43	<0.01
Water (500m)	0.33	0.01
Forest (100m)	0.30	0.02
Water (100m)	0.29	0.02
Distance to Forest Edge	0.25	0.05
Distance to Interior Forest	-0.37	<0.01
Agriculture (1000m)	-0.39	<0.01
Agriculture (100m)	-0.40	<0.01
Agriculture (500m)	-0.40	<0.01
Agriculture (2000m)	-0.44	<0.01
Forest Interior Abundance 1999		
Forest Width	0.48	<0.01
Distance to Forest Edge	0.37	<0.01
Forest (100m)	0.35	<0.01
Agriculture (100m)	-0.27	0.04
Shrubland (100m)	-0.32	0.01

Distance to Interior Forest	-0.49	<0.01
Forest Interior Abundance 2000		
Forest (1000m)	0.48	<0.01
Forest (500m)	0.43	<0.01
Rangeland (2000m)	0.43	<0.01
Forest (2000m)	0.42	<0.01
Water (500m)	0.32	0.01
Forest (100m)	0.30	0.02
Rangeland (1000m)	0.30	0.02
Water (100m)	0.29	0.02
Distance to Forest Edge	0.27	0.03
Forest Width	0.25	0.05
Agriculture (1000m)	-0.38	<0.01
Agriculture (500m)	-0.39	<0.01
Distance to Interior Forest	-0.39	<0.01
Agriculture (100m)	-0.41	<0.01
Agriculture (2000m)	-0.43	<0.01

Table 7-4. Habitat Factors Correlated with Forest Interior Species Richness or Abundance.

Correlation	**Spearman R**	***p*-level**
Forest Interior Richness 1999		
Nest Parasite/Robber Richness	0.29	0.02
Nest Parasite/Robber Abundance	0.28	0.03
Forest Interior Abundance 1999		
Nest Parasite/Robber Richness	0.30	0.02
Nest Parasite/Robber Abundance	0.30	0.02

Many landscape factors were related to the forest interior species community; the 2000 breeding season results were similar to the results obtained when looking at the overall avian community, but the 1999 breeding season showed more results in the forest interior species subclass than were seen in the overall avian community. The amount of forest of various distances showed up as a significant relationship in both years for richness and abundance, with R values ranging between 0.3 (2000 richness and abundance, forest within 100 m) to 0.49 (2000 richness, forest within 1000 m). The strongest positive relationships for forest interior species richness were forest width (R = 0.49) in 1999 and forest within 1000m (R = 0.48) in 2000. The strongest negative relationships were at the same magnitude, with agriculture within 2000 m during the 2000 breeding season (R = –0.44) and distance to interior forest during the 1999 season (R = –0.49) being the two largest negative correlations. With respect to forest interior abundance, the strongest positive relationships occurred with forest width in 1999 (R = 0.48) and forest within 1000 m in 2000 (R = 0.48), and the strongest negative relationships were agriculture within 2000 m in the 2000 season (R = –0.43) and distance to interior forest in the 1999 season (R = –0.49).

The only “habitat” factors that showed a relationship to the forest interior avian community in all years for both richness and abundance were nest parasites and robbers in 1999, which, again, are not habitat factors at all in a strict sense. The forest interior avian community showed no relationship with any habitat variables in the 2000 breeding season. When seen as a whole in the context of this analysis, the forest interior avian community seems to be influenced strictly by landscape variables. However, breaking the correlation analysis down into forest subclass type (i.e., patch and corridor) showed a few more relationships not apparent when the Greenbelt as a whole was analyzed. These relationships and others are presented in the following section.

Forest Patch and Corridor Correlations

For both years, and for each subclass of forest (patch and corridor), a total of 376 correlations were run: 216 correlations were run between the breeding birds data set (richness and abundance, both overall and for forest interior birds) and landscape variables, and 160 correlations were run between the breeding birds and habitat variables. Within those subclasses of correlations, half of the total correlations were run on overall species richness and abundance, and half were run on forest interior species richness and abundance.

Overall Species

Within the corridor subclass (43 stations), 29 significant ($p < 0.05$) correlations were found between overall species richness or abundance and landscape or habitat variables (Table 7-5). Within the patch subclass (19 stations), 11 significant correlations were found while exploring the same potential relationships (Table 7-6).

Table 7-5. Correlations between Overall Species Richness or Abundance and Landscape/Habitat Variables in Corridor Forests.

Correlation	**Spearman R**	***p*-level**
Overall Richness 1999		
Pileated Woodpecker HSI	-0.31	0.04
Development (1000m)	-0.39	0.01
Overall Richness 2000		
Forest (1000m)	0.46	<0.01
Forest (2000m)	0.44	<0.01
Forest (500m)	0.39	0.01

Rangeland (2000m)	0.38	0.01
Forest (100m)	0.36	0.02
Number of Large Snags	0.32	0.04
Distance to Interior Forest	-0.31	0.04
Agriculture (1000m)	-0.36	0.02
Agriculture (500m)	-0.38	0.01
Agriculture (100m)	-0.39	0.01
Development (2000m)	-0.41	0.01
Overall Abundance 1999		
Distance to Nearest Edge	0.36	0.02
Shrubland (1000m)	0.35	0.02
Distance to Interior Forest	-0.39	0.01
Overall Abundance 2000		
Forest (500m)	0.45	<0.01
Forest (1000m)	0.44	<0.01
Forest (2000m)	0.41	0.01
Rangeland (2000m)	0.40	0.01
Forest (100m)	0.39	0.01
Distance to Nearest Edge	0.31	0.04
Nest Parasite/Robber Abundance	0.26	0.04
Agriculture (2000m)	-0.30	0.05
Agriculture (1000m)	-0.34	0.02
Development (2000m)	-0.39	0.01
Agriculture (500m)	-0.40	0.01
Agriculture (100m)	-0.41	0.01
Distance to Interior Forest	-0.42	0.01

In the forest corridors of the Ray Roberts Greenbelt, the primary landscape factors positively correlated with the richness and abundance of the overall avian community were forests during the 2000 breeding season with R values from 0.36 to 0.46. Agriculture, development, and distance to interior forest were all the primary negative correlations, with all of these correlation coefficients around –0.4. In the 1999 breeding season, overall richness was only correlated with the Pileated Woodpecker HSI values and development within 1000 m; both of these correlations were negative (R = –0.31 and

R = –0.39, respectively). Abundances of birds during that same season were similarly correlated with few factors; distance to nearest edge (R = 0.36), shrubland within 1000m (R = 0.35), and distance to interior forest (R = –0.39) were the only factors with a significant correlation with the overall bird community of the corridor forests.

Table 7-6. Correlations between Overall Species Richness or Abundance and Landscape/Habitat Variables in Patch Forests.

Correlation	**Spearman R**	***p*-level**
Overall Richness 1999		
Nest Parasite/Robber Abundance	0.49	0.03
Nest Parasite/Robber Richness	0.48	0.04
Overall Richness 2000		
Nest Parasite/Robber Richness	0.56	<0.01
Nest Parasite/Robber Abundance	0.52	0.02
Overall Abundance 1999		
Nest Parasite/Robber Abundance	0.59	0.01
Nest Parasite/Robber Richness	0.56	0.01
Number of Forest Canopy Layers	-0.46	0.05
Development (1000m)	-0.49	0.03
Overall Abundance 2000		
Nest Parasite/Robber Richness	0.74	<0.01
Nest Parasite/Robber Abundance	0.73	<0.01
Shrubland (500m)	-0.48	0.04

As was the case for the avian community of the entire Greenbelt, the primary "habitat" correlations in patch forests were between overall species richness and abundance with nest parasites and robbers in both years, with correlation coefficients as high as 0.74 (2000 abundance, nest parasite/robber richness). No other habitat factors were significantly correlated with the avian community of the patch forests. Only two landscape variables were correlated with this community: shrubland within 500 m (R = –0.48) for abundance in 1999, and development within 1000m (R = –0.49) for abundance during the 2000 breeding season.

Forest Interior Species

For forest interior species, the number of significant correlations were approximately the same as compared with the overall avian community, with more occurring with corridor forests than with patch forests. In corridor forests, 28 significant correlations were found between forest interior richness or abundance and landscape or habitat variables (Table 7-7), while only 7 significant correlations were found for these relationships in patch forests (Table 7-8).

Table 7-7. Correlations between Forest Interior Species Richness or Abundance and Landscape/Habitat Variables in Corridor Forests.

Correlation	**Spearman R**	**p-level**
Forest Interior Richness 1999		
Forest Width	0.40	0.01
Distance to Interior Forest	-0.39	0.01
Forest Interior Richness 2000		
Forest (500m)	0.50	<0.01
Forest (1000m)	0.48	<0.01
Rangeland (2000m)	0.46	<0.01
Forest (2000m)	0.44	<0.01
Forest (100m)	0.38	0.01
Water (500m)	0.38	0.01
Water (100m)	0.31	0.04
Agriculture (1000m)	-0.36	0.02
Agriculture (500m)	-0.38	0.01
Agriculture (2000m)	-0.41	0.01
Agriculture (100m)	-0.44	<0.01

Distance to Interior Forest	-0.47	<0.01
Forest Interior Abundance 1999		
Forest Width	0.40	0.01
Distance to Interior Forest	-0.39	0.01
Forest Interior Abundance 2000		
Forest (500m)	0.50	<0.01
Forest (1000m)	0.49	<0.01
Forest (2000m)	0.45	<0.01
Rangeland (2000m)	0.45	<0.01
Forest (100m)	0.38	0.01
Water (500m)	0.38	0.01
Water (100m)	0.33	0.03
Agriculture (1000m)	-0.36	0.02
Agriculture (500m)	-0.38	0.01
Agriculture (2000m)	-0.40	0.01
Agriculture (100m)	-0.43	<0.01
Distance to Interior Forest	-0.46	<0.01

Like the overall species correlations in corridors, above, forest landscape factors were the most important variables in terms of the relative strength of the correlation coefficients in the forest interior bird community of the forest corridors. No habitat factors were significantly correlated with the corridor bird community; only landscape factors showed any significant relationship to this bird community. The 1999 breeding season showed correlations solely with forest width and distance to interior forest in both richness and abundance classes, with R values for forest width of 0.4 for both richness and abundance, and –0.39 for richness and abundance when correlated with distance to interior forest. In the 2000 breeding season, agriculture and distance to interior forest were the primary negative correlations, with R values ranging from –0.36 (2000 richness and abundance, agriculture within 1000 m) to –0.47 (2000 richness, distance to interior forest).

Table 7-8. Correlations between Forest Interior Species Richness or Abundance and Landscape/Habitat Variables in Patch Forests.

Correlation	**Spearman R**	***p*-level**
Forest Interior Richness 1999		
Nest Parasite/Robber Richness	0.54	0.02
Nest Parasite/Robber Abundance	0.52	0.02
Tree Density	0.48	0.04
Forest Interior Richness 2000		
Shrubland (500m)	-0.49	0.03
Forest Interior Abundance 1999		
Nest Parasite/Robber Richness	0.59	0.01
Nest Parasite/Robber Abundance	0.59	0.01
Tree Density	0.52	0.02

Again, the primary "habitat" correlations in patch forests were between forest interior species richness and abundance with nest parasites and robbers in 1999. The only true habitat factor correlated with richness and abundance in 1999 was tree density (R = 0.48 and 0.52, respectively). No landscape factors were correlated with the forest interior birds within the patch forests. No significant correlations were found between habitat or landscape variables and the abundances of the forest interior bird community of the patch forests in 2000; in that year and season, the only correlation found was a negative one between forest interior species richness and shrubland within 500 m (R = –0.49).

Discussion

A total of 792 correlations were run between the overall and the forest interior avian communities of the Ray Roberts Greenbelt and the landscape and habitat features that provide the ecological context for these birds. In the analyses that encompassed all 62 stations within the Greenbelt, only 13 correlations with habitat factors were significant, while 72 correlations with landscape factors were significant. In the analyses that divided the forest into patch stations and corridor stations, only 3 of 29 significant correlations were found between habitat variables and the overall avian community of the corridor forests. The remaining 26 correlations were with landscape variables. In patch forests, 11 significant correlations were found for the overall avian community; 2 were landscape factors (development and shrubland), 1 was a habitat factor (number of forest canopy layers), and the rest were correlations with nest parasites and robbers (and thus are not habitat factors in a strict sense). For forest interior species, the patterns in corridor and patch forests are similar: the forest interior species in corridors were associated with 28 landscape factors and no habitat factors. In patch forests, the forest interior species were associated with just seven variables, 4 of which were nest parasites/robbers; two correlations were with tree density, a habitat factor, and one correlation was with shrubland, a landscape factor. This was the only instance in which more habitat factors were associated with birds than were landscape factors. The majority of these results suggest that landscape factors may be the driving force in the richness, abundance, and distribution of the avian communities—overall and forest interior—under consideration in this study. The possible reasons for these patterns are discussed further in successive chapters.

There were 11 correlations of landscape and habitat factors with the overall avian community that had R values greater than or equal to 0.4 or –0.4, which were the highest correlations found in this study. As such, they are defined herein as "strong" correlations, as—relative to other significant correlations in this study—they represent the best choices for explorations of possible thresholds in avian species' responses to habitat and landscape factors in the Ray Roberts Greenbelt. These strong correlations are listed for the overall avian community in Table 7-9, and for forest interior species in Table 7-10.

Table 7-9. Major correlative habitat and landscape factors associated with the overall avian community.

Richness	**Abundance**
	Agriculture (100m)
	Agriculture (500m)
	Development (1000m)
Development (2000m)	
	Distance to Interior Forest
	Forest (500m)
Forest (1000m)	Forest (1000m)
Forest (2000m)	Forest (2000m)
	Number of Forest Canopy Layers
	Rangeland (2000m)
	Shrubland (500m)

Most of these correlations are associated with abundance; overall richness was strongly correlated with only a few factors, which were the landscape factors of forest and development. The abundance category has 11 major correlations, of which only one is a habitat factor (number of forest canopy layers); the rest were landscape factors. Agriculture, development, shrubland, number of canopy layers, and distance to interior forest were all negative correlations, while forest and rangeland were positively correlated with the avian community. Forest was the only factor that had a strong association with both richness and abundance.

Table 7-10. Major correlative habitat and landscape factors associated with the forest interior avian community.

Richness	**Abundance**
Agriculture (100m)	Agriculture (100m)
Agriculture (2000m)	Agriculture (2000m)
Agriculture (500m)	
Distance to Interior Forest	Distance to Interior Forest
Forest (1000m)	Forest (1000m)
Forest (2000m)	Forest (2000m)
Forest (500m)	Forest (500m)
Forest Width	Forest Width
Rangeland (2000m)	Rangeland (2000m)
Shrubland (500m)	
Tree Density	Tree Density

Unlike the strong correlations in the overall avian community, the correlations with the forest interior species in Table 7-10 were essentially the same across both richness and abundance. Shrubland was the only factor that was correlated with species richness but not with abundance. Only one habitat factor—tree density—had a strong relationship with forest interior species richness and abundance; the remaining 11 factors were all within the landscape category. Tree density, forest width, rangeland, and forest were all positively correlated with the avian richness and abundance, while agriculture, development, distance to interior forest, and shrubland all had negative associations with the bird community.

The relative strength of these correlations suggests a starting place for an exploration of the major landscape and habitat factors that could influence the richness and abundance of avian communities within the Ray Roberts Greenbelt. Therefore, these correlations will be used to explore possible thresholds in avian communities' responses to landscape and habitat variables. A discussion of possible reasons for each of these associations and an exploration of these correlations as potential thresholds both occur in the next chapter.

CHAPTER 8

THRESHOLDS IN AVIAN/HABITAT/LANDSCAPE RELATIONSHIPS

Overview

In order to explore potential thresholds in avian community responses to landscape and habitat factors, the highest positive and the highest negative correlation were chosen for each avian community (all species and forest interior species, richness and abundance) in three classes: whole greenbelt, corridor forests, and patch forests. A total of 25 associations subsequently were chosen from the 53 associations that had correlation coefficients greater than or equal to 0.4 or –0.4 (see Chapter 7). These associations are analyzed in this chapter for potential thresholds in the presence of high richness or abundance in the avian communities.

Two types of potential thresholds are explored. In one method, a second order polynomial line is fitted to the data, and the highest or lowest peak of the line is used to delineate a potential threshold for positive or negative relationships, respectively. The line is plotted on each figure with 95% confidence intervals to get a feel for the variation in the data, but the line itself is chosen for the delineation of the potential threshold. The second method uses the upper quartile of the avian community variable under consideration, and a threshold is chosen for the point on the x axis where lowest data point above (for positive associations) or below (for negative associations) the upper quartile occurs. This region has a box drawn around it on each figure to clarify the region for which a threshold is chosen.

Overall Avian Community Thresholds

The eight relationships chosen for the analysis of potential thresholds for the overall avian community within the Ray Roberts Greenbelt include the landscape factors of forest, agriculture, development, shrubland, and distance to interior forest. No habitat factors were among the highest correlations (negative or positive) for all species in the whole Greenbelt, the corridor forests, and the patch forests.

For the whole Greenbelt, only the abundance of all species in the 2000 breeding season showed a strong correlation with any factors. Figures 8-1 and 8-2 show the scatterplots of all species abundance for the whole Greenbelt with forest within 500 m and agriculture within 100 m, respectively. For the forest factor (Figure 8-1), which was related positively with all species abundance in 2000, potential thresholds exist at 35% and 90% (all thresholds for this section are summarized in Table 8-1). The fitted polynomial line did not peak at all, suggesting that a threshold based upon this approach exists above 90% forest cover within 500 m. The upper quartile of abundance (UQ = 16) did not occur until at least 35% of the area was forested. The agricultural factor was related negatively to abundance, and this factor also did not show a peak in the fitted line, suggesting that a threshold may exist only where no agriculture occurs within 100 m. The upper quartile occurred only when agriculture represented less than 30% of the landscape within 100 m.

Figure 8-1. Scatterplot and associated thresholds of the relationship between the amount of forest within 500 m and abundance for the overall avian community of the entire Greenbelt during the 2000 breeding season.

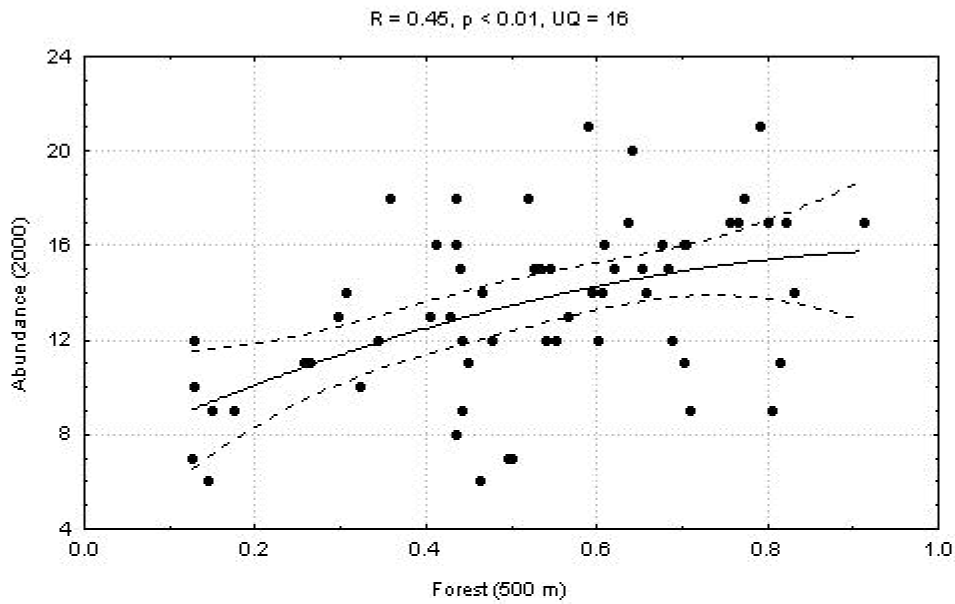
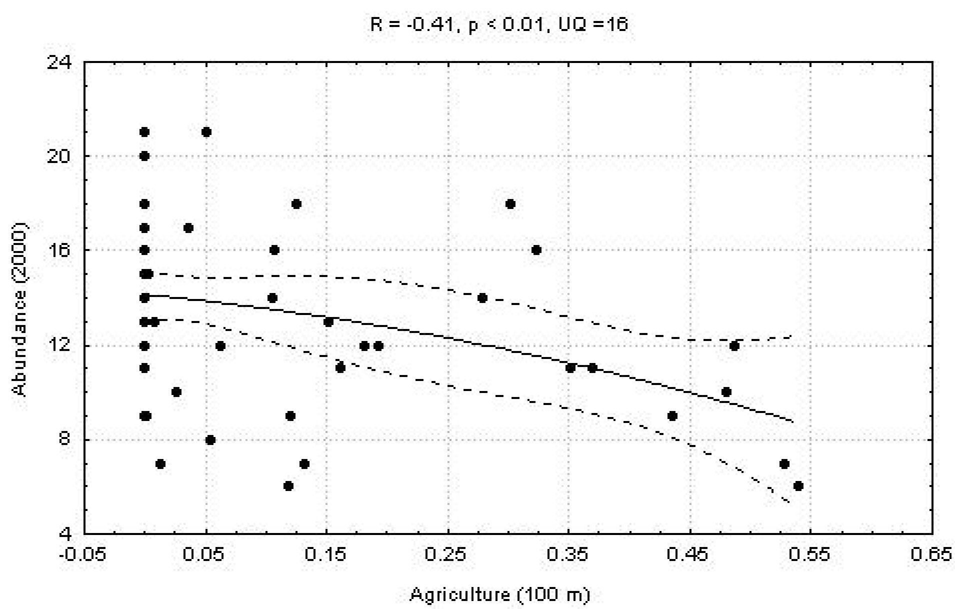


Figure 8-2. Scatterplot and associated thresholds of the relationship between the amount of agriculture within 100 m and abundance for the overall avian community of the entire Greenbelt during the 2000 breeding season.



For the corridor forest, four factors were related to the richness and abundance of the overall avian community during the 2000 breeding season. Figures 8-3 and 8-4 show the scatterplots of all species richness for the corridor forests with respect to forest within 1000 m and development within 2000 m, respectively. Both the forest factor (Figure 8-3), which showed a positive relationship to species richness, and the negatively related development factor (figure 8-4), did not show peaks in their fitted lines, which suggests that any thresholds for these two lie at above 68% forest and at 0% development. The upper quartile for species richness occurs at 9 species; for forest, this threshold occurred above 35%, with the same threshold for development occurring below 6%. Species abundance in the 2000 breeding season showed strong correlations with forest within 500 m (positive) and the distance to interior forest (negative). Figure 8-5 (forest within 500 m) and figure 8-6 (distance to interior forest) do show peaks in their fitted lines, which occur at 80% forest and 1240 m, respectively. The upper quartile for species abundance is 16; this threshold occurred above 35% forest within 500 m, and below 840 m distance from the nearest interior forest area.

Figure 8-3. Scatterplot and associated thresholds of the relationship between the amount of forest within 1000 m and richness for the overall avian community of the corridor forests during the 2000 breeding season.

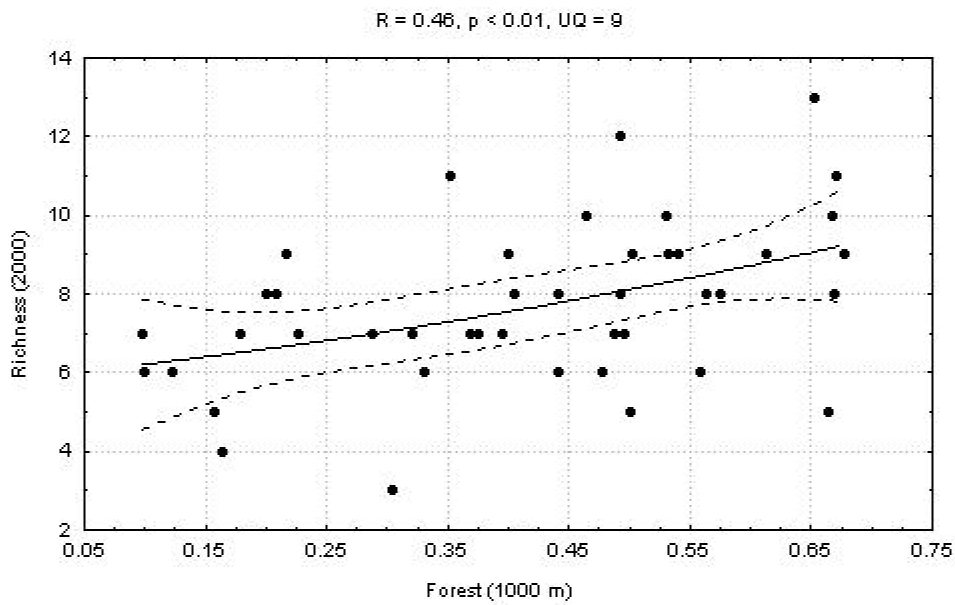


Figure 8-4. Scatterplot and associated thresholds of the relationship between the amount of development within 2000 m and richness for the overall avian community of the corridor forests during the 2000 breeding season.

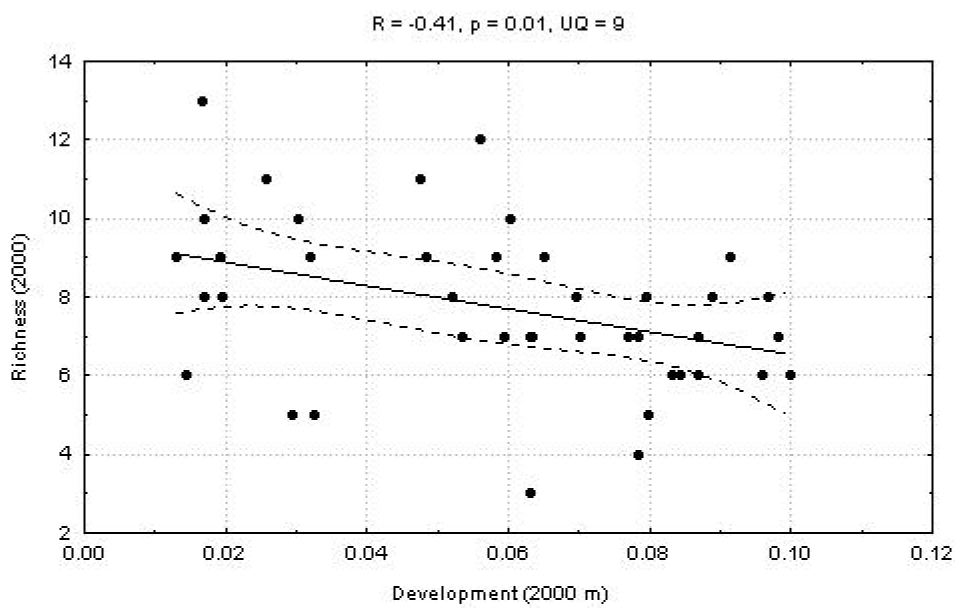


Figure 8-5. Scatterplot and associated thresholds of the relationship between the amount of forest within 500 m and abundance for the overall avian community of the corridor forests during the 2000 breeding season.

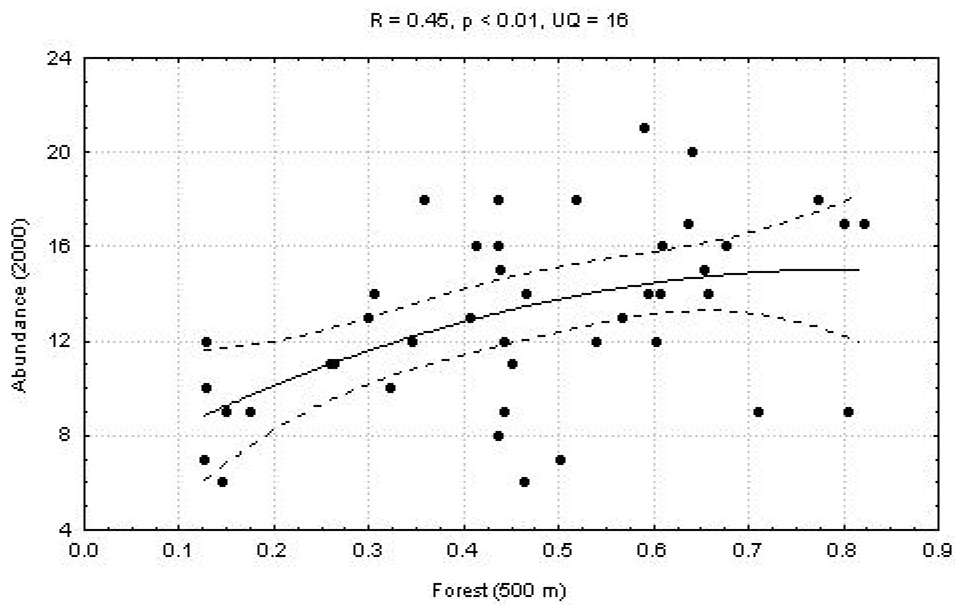
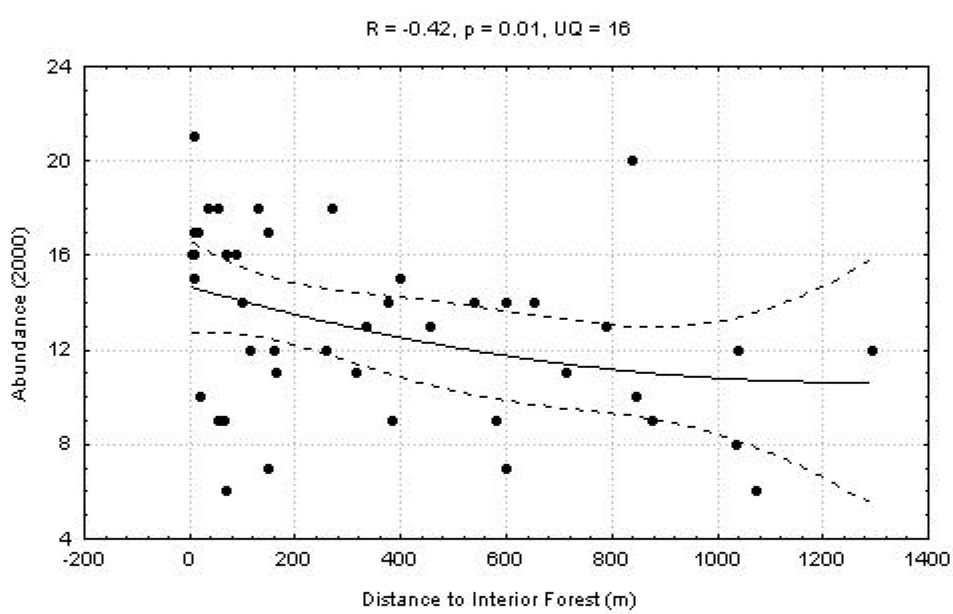


Figure 8-6. Scatterplot and associated thresholds of the relationship between the distance to interior forest and abundance for the overall avian community of the corridor forests during the 2000 breeding season.



For the patch forests, no one factor showed a strong positive correlation with either species richness or abundance in either year; the only strong correlations occurred were negative, between species abundance in both years with development within 1000m in 1999 and with shrubland within 500 m in 2000. Figures 8-7 and 8-8 show the scatterplots of all species abundance for patch forests with development within 1000 m and shrubland within 500 m, respectively. For the development factor, potential thresholds exist at 10% for the fitted line, and less than 1% for the upper quartile (UQ = 15). For shrubland in 2000, potential thresholds exist at 5% for the fitted line, and less than 3% for the upper quartile (UQ = 16).

Figure 8-7. Scatterplot and associated thresholds of the relationship between the amount of development within 1000 m and abundance for the overall avian community of the patch forests during the 1999 breeding season.

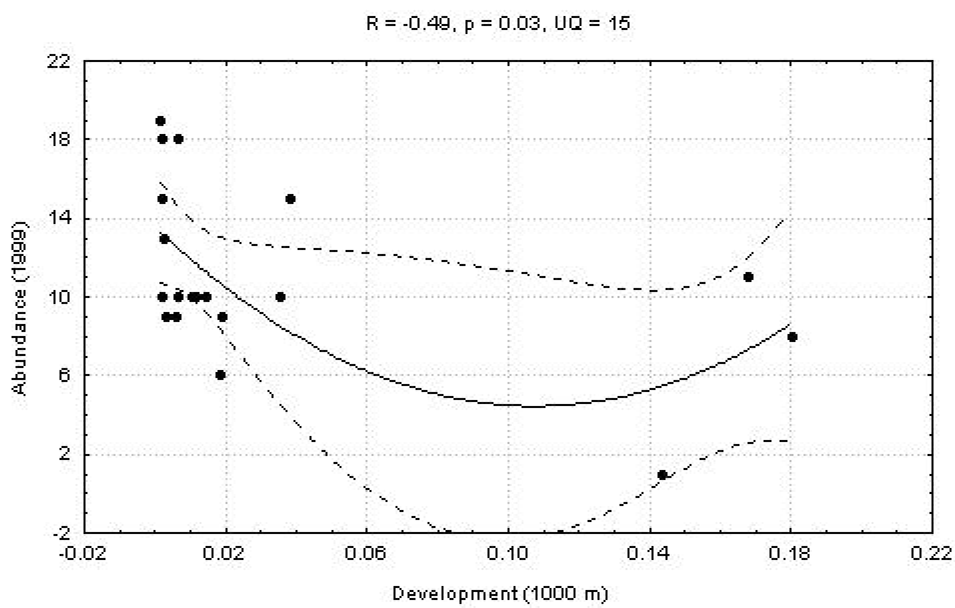
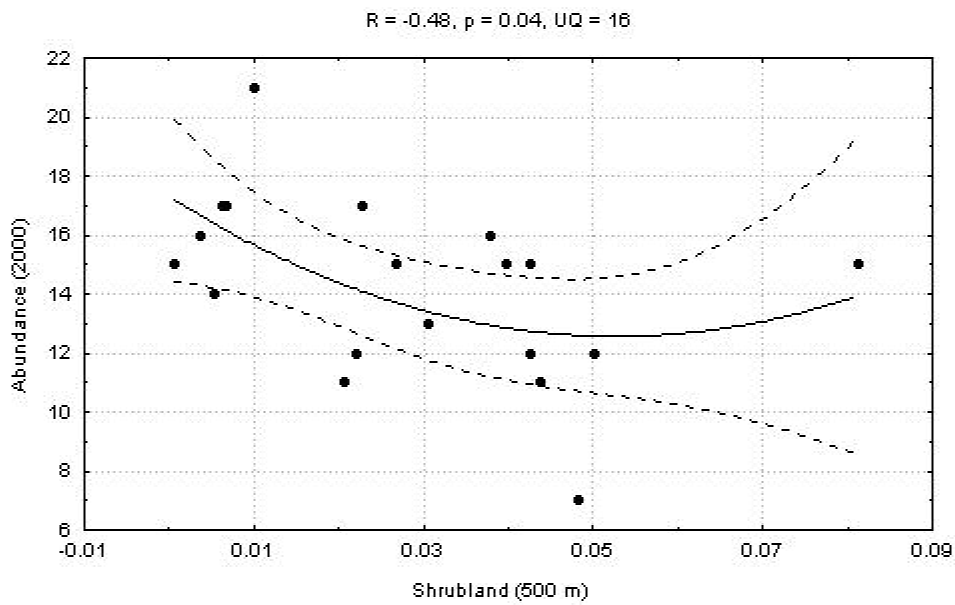


Figure 8-8. Scatterplot and associated thresholds of the relationship between the amount of shrubland within 500 m and abundance for the overall avian community of the patch forests during the 2000 breeding season.



The potential thresholds for all species richness and abundance in the Greenbelt for both years are summarized in Table 8-1, and discussed at the end of the chapter.

Table 8-1. Summary of potential thresholds in the overall avian community (diagramed in Figures 8-1 through 8-8).

Forest Class, Metric	**Habitat/Landscape Factor**	**Fitted Line Threshold**	**Upper Quartile Threshold**
Whole Greenbelt, Abundance (2000)	Forest (500m)	None (90%)	> 35%
Whole Greenbelt, Abundance (2000)	Agriculture (100m)	None (0%)	< 30%
Corridor, Richness (2000)	Forest (1000m)	None (68%)	> 35%
Corridor, Richness (2000)	Development (2000m)	None (0%)	< 6%
Corridor, Abundance (2000)	Forest (500m)	80%	> 35%

Corridor, Abundance (2000)	Distance to Interior Forest	1240 m	< 840 m
Patch, Abundance (1999)	Development (1000m)	10%	< 1%
Patch, Abundance (2000)	Shrubland (500m)	5%	< 3%

Forest Interior Avian Community Thresholds

Entire Greenbelt Forest Interior Avian Community

There were eight relationships chosen for the analysis of potential thresholds for the forest interior avian community for the entire Greenbelt. Like the overall avian community, no habitat factors were among the highest correlations (negative or positive) for forest interior species in the whole Greenbelt. The landscape factors explored for potential thresholds in the forest interior community include the landscape factors of forest, forest width (both positively related), agriculture, and distance to interior forest (both negatively related).

For the whole Greenbelt, richness and abundance of the forest interior species had strong positive and negative correlations in both years. Figures 8-9 and 8-10 show the strongest positive and negative relationships, respectively, for forest interior species richness in 1999. The positive relationship is for forest width, with the fitted line showing a potential threshold at 470 m, while the upper quartile (UQ = 1) threshold occurred above 200 m. The negative correlation with richness shows a low peak in the fitted line at 500 m in distance to interior forest, while the upper quartile only occurred at less than 100 m. The same two factors were the strongest correlations in the forest interior species abundance in 1999, and had very similar thresholds. As was the case with richness, the fitted line for width found a threshold of 470 m, and the upper quartile appeared in forests wider than 200 m. The fitted line for distance to interior forest found a slightly lower threshold, at 475 m, while the upper quartile was identical to the richness threshold at less than 100 m. The forest interior species thresholds for abundance in the 1999 breeding season are presented in Figures 8-11 and 8-12.

Figure 8-9. Scatterplot and associated thresholds of the relationship between forest width and richness for the forest interior avian community of the entire Greenbelt during the 1999 breeding season.

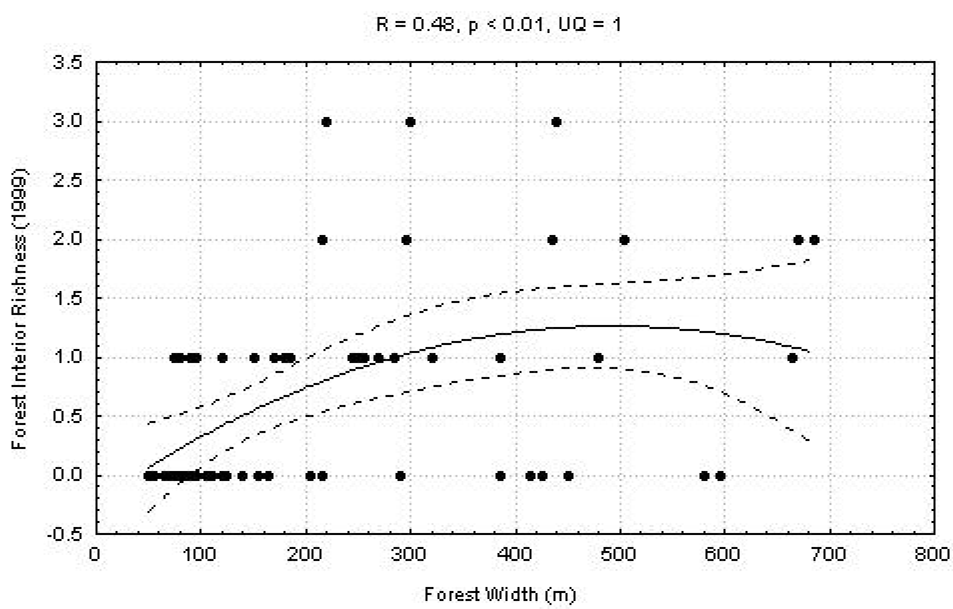


Figure 8-10. Scatterplot and associated thresholds of the relationship between the distance to interior forest and richness for the forest interior avian community of the entire Greenbelt during the 1999 breeding season.

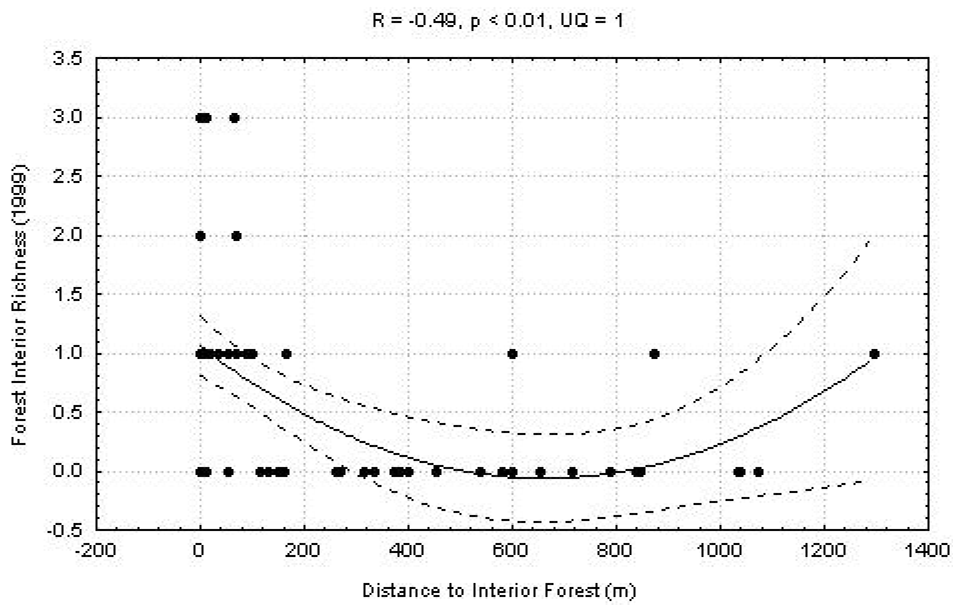


Figure 8-11. Scatterplot and associated thresholds of the relationship between forest width and abundance for the forest interior avian community of the entire Greenbelt during the 1999 breeding season.

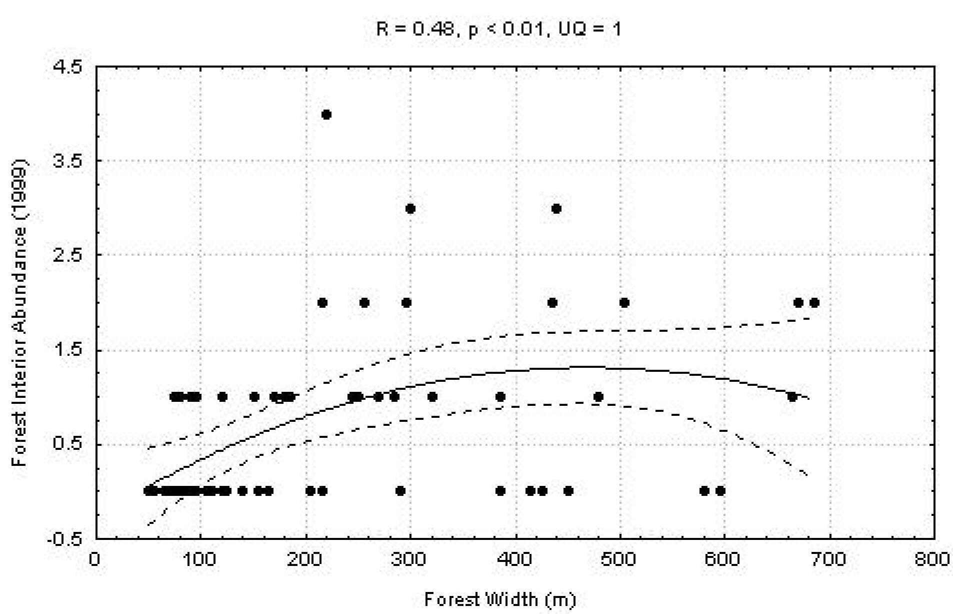
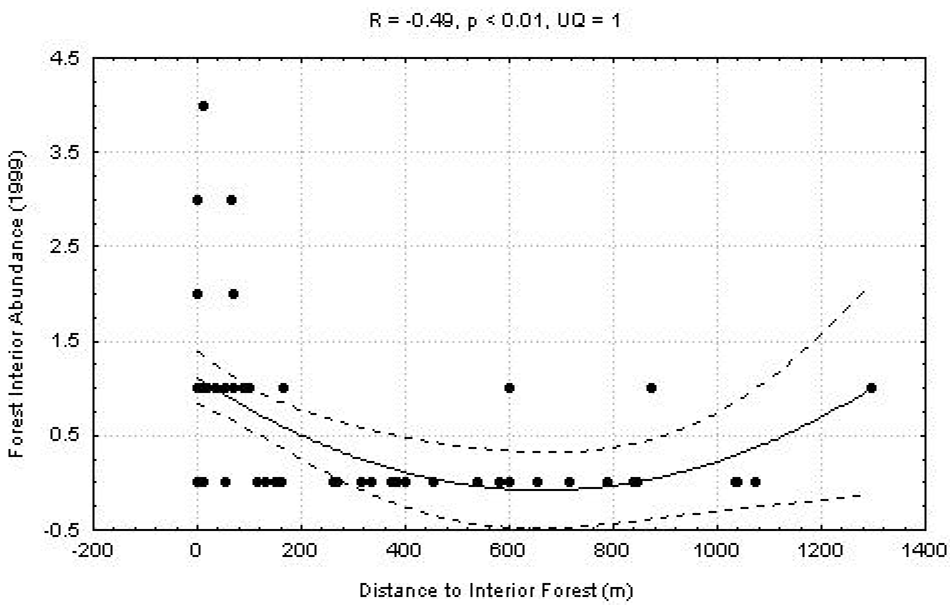


Figure 8-12. Scatterplot and associated thresholds of the relationship between the distance to interior forest and abundance for the forest interior avian community of the entire Greenbelt during the 1999 breeding season.



For the 2000 breeding season, the percent of forest within 1000 m was the strongest positive association for both richness and abundance of the forest interior birds, while agriculture within 2000 m was the strongest negative association for both classes. Figures 8-13 and 8-14 show the relationships for richness, and figures 8-15 and 8-16 show the similar relationships with abundance. None of the fitted lines showed peaks, with maximum positive values for percent forest at 67% for both richness and abundance. The threshold for the upper quartile of richness (UQ = 1) and abundance (UQ = 2) occurred at forest percentages of greater than 35%. Agriculture, as might be expected, had a negative association, and fitted lines also found no peak value, with a minimum value of 8%. Upper quartile thresholds in both richness and abundance were at less than 48% and 50%, respectively.

Figure 8-13. Scatterplot and associated thresholds of the relationship between the amount of forest within 1000 m and richness for the forest interior avian community of the entire Greenbelt during the 2000 breeding season.

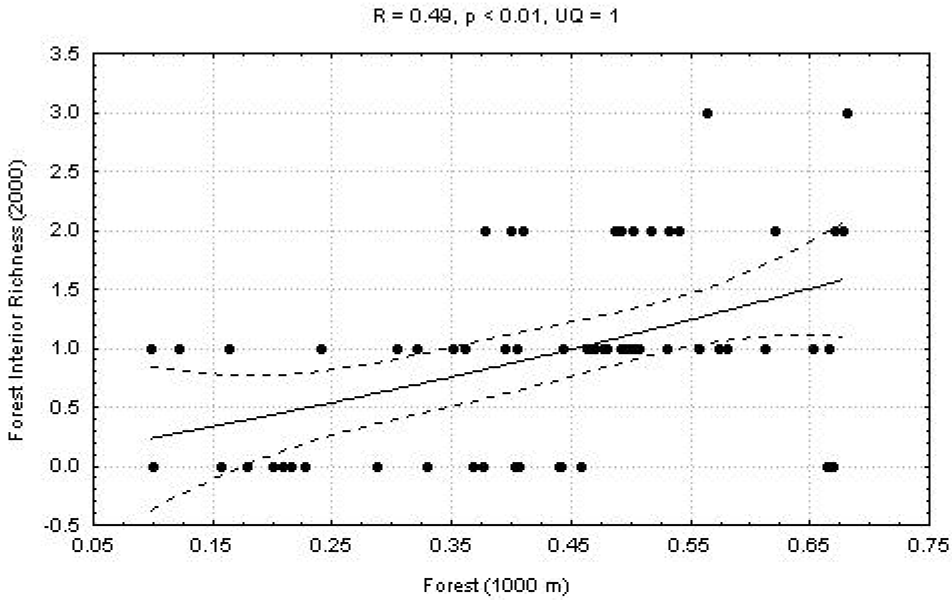


Figure 8-14. Scatterplot and associated thresholds of the relationship between the amount of agriculture within 2000 m and richness for the forest interior avian community of the entire Greenbelt during the 2000 breeding season.

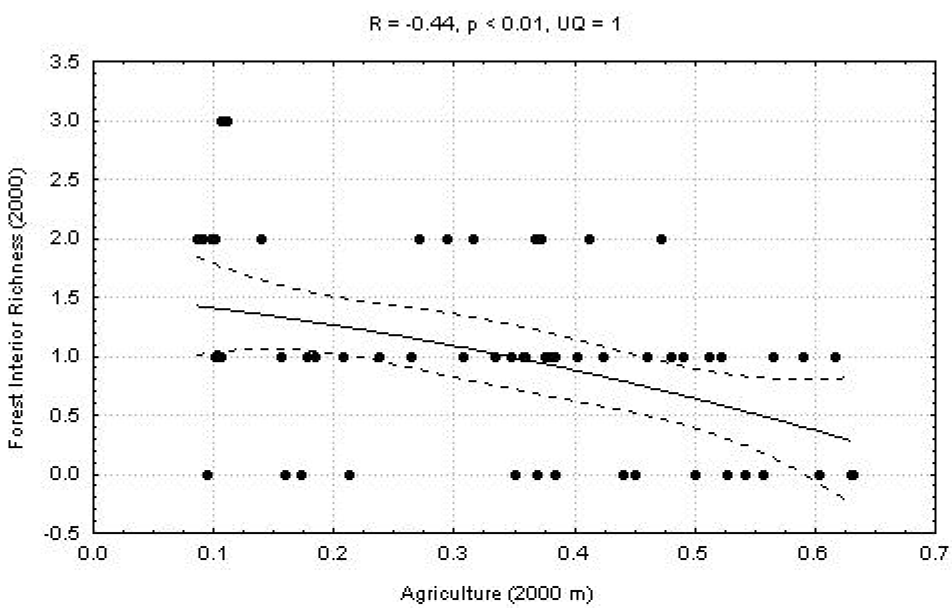


Figure 8-15. Scatterplot and associated thresholds of the relationship between the amount of forest within 1000 m and abundance for the forest interior avian community of the entire Greenbelt during the 2000 breeding season.

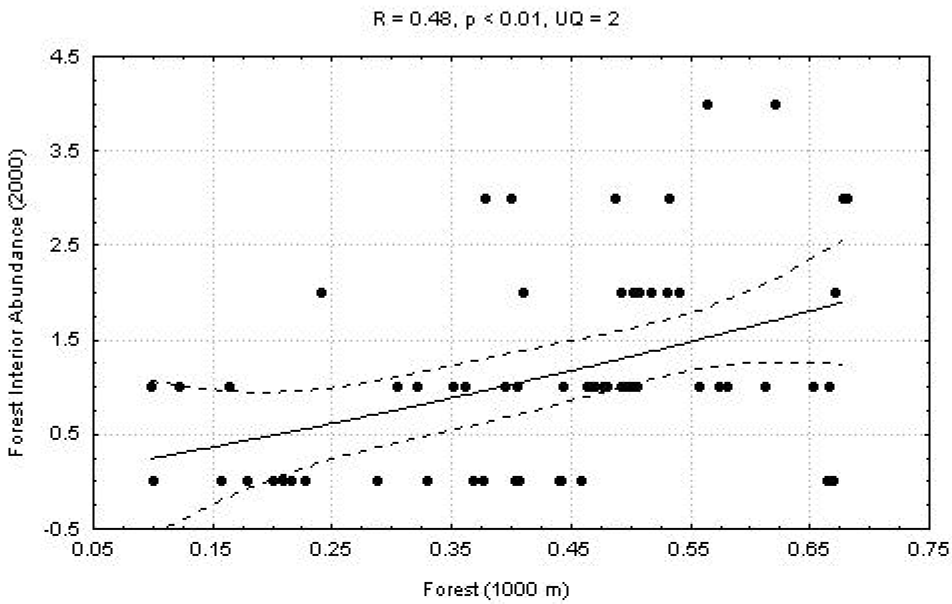
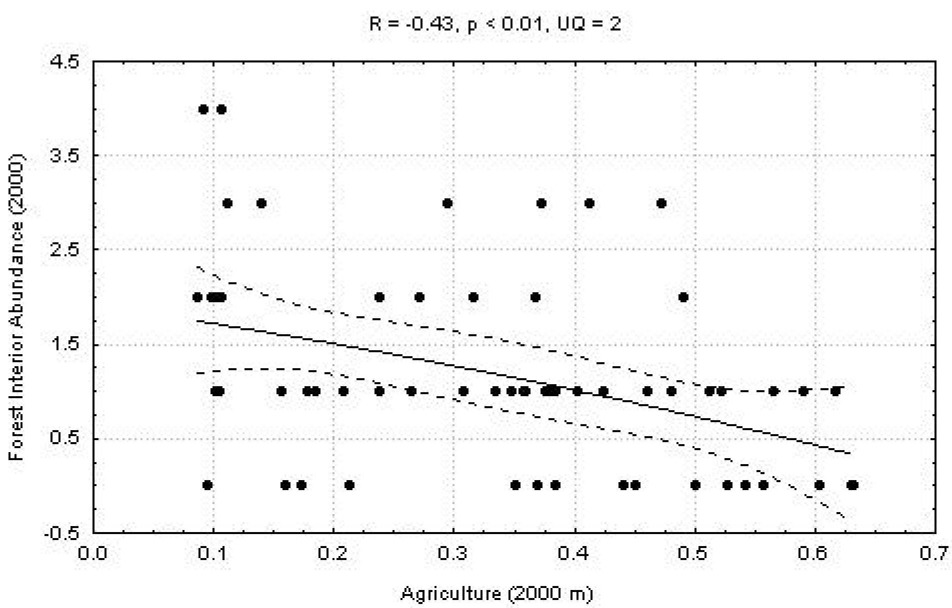


Figure 8-16. Scatterplot and associated thresholds of the relationship between the amount of agriculture within 2000 m and abundance for the forest interior avian community of the entire Greenbelt during the 2000 breeding season.



The potential thresholds for forest interior species richness and abundance in the entire Greenbelt for both years are summarized in Table 8-2, and discussed at the end of the chapter.

Table 8-2. Summary of potential thresholds in the forest interior avian community for the whole Greenbelt (diagramed in Figures 8-9 through 8-16).

Metric	**Habitat/Landscape Factor**	**Fitted Line Threshold**	**Upper Quartile Threshold**
Richness (1999)	Forest Width	470 m	> 200 m
Richness (1999)	Distance to Interior Forest	500 m	< 100 m
Abundance (1999)	Forest Width	470 m	> 200 m
Abundance (1999)	Distance to Interior Forest	475 m	< 100 m
Richness (2000)	Forest (1000m)	None (67%)	> 35%
Richness (2000)	Agriculture (2000m)	None (8%)	< 48%
Abundance (2000)	Forest (1000m)	None (67%)	> 35%
Abundance (2000)	Agriculture (2000m)	None (8%)	< 50%

Corridor and Patch Forest Interior Avian Community

Six associations were explored for thresholds in the forest interior bird community of the corridor forests, while three were examined for this community in patch forests. These associations are summarized in Table 8-3, which occurs at the end of this section.

In the corridor forests, forest width, distance to interior forest, and percent forest within 500 m were the strongest correlations, which are shown in the scatterplots of Figures 8-17 through 8-22. Forest width was positively associated with both richness and abundance in 1999 (Figures 8-17 and 8-18, respectively); fitted line thresholds were the same for both classes, occurring at 250 m. The upper quartile threshold (UQ = 1 for both variables) was similar, occurring above 220 m for richness and 210 m for abundance. No strong negative correlations were found between the forest interior birds of the corridor forests and either landscape or habitat factors.

Figure 8-17. Scatterplot and associated thresholds of the relationship between forest width and richness for the forest interior avian community of the corridor forests during the 1999 breeding season.

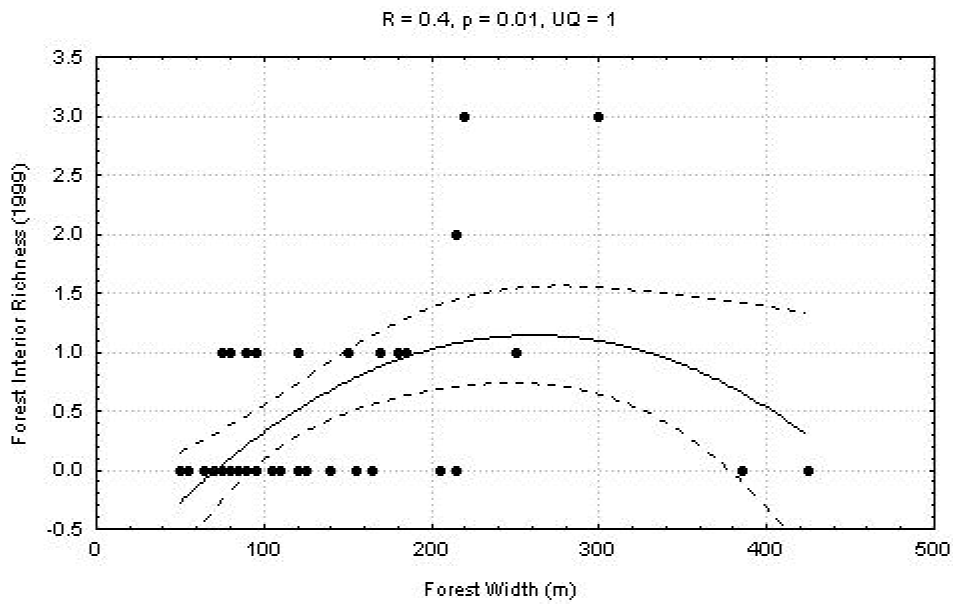
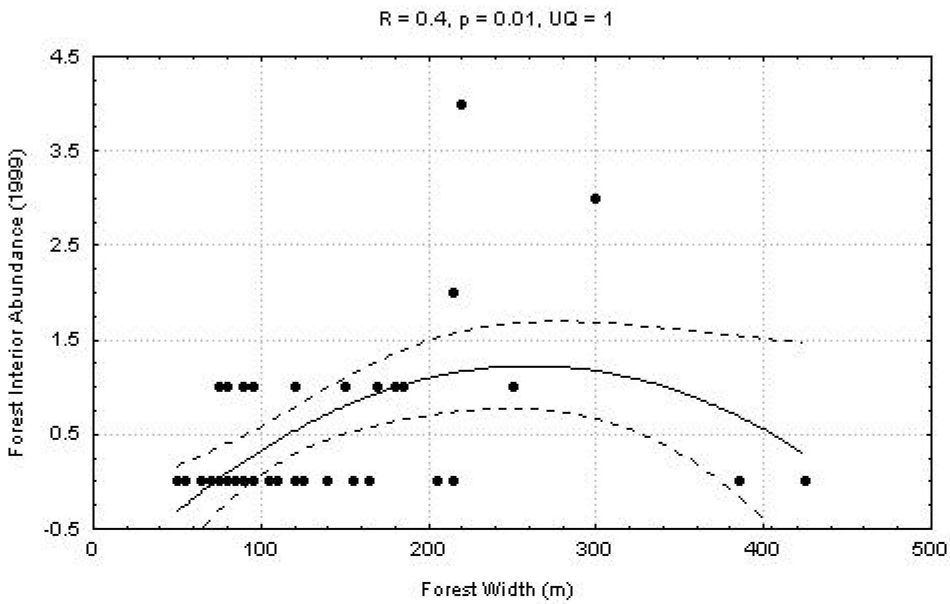


Figure 8-18. Scatterplot and associated thresholds of the relationship between forest width and abundance for the forest interior avian community of the corridor forests during the 1999 breeding season.



Forest interior species richness in the 2000 breeding season was positively associated with the amount of forest within 500 m (Figure 8-19), and negatively associated with the distance to interior forest (Figure 8-20). There was no peak in the fitted line for amount of forest, which had a maximum value of 83%. The upper quartile (UQ = 1) threshold occurred above 42%. The negative association with distance to interior forest found a fitted line threshold at 830 m, while the upper quartile (UQ = 1) occurred below 140 m.

Figure 8-19. Scatterplot and associated thresholds of the relationship between the amount of forest within 500 m and richness for the forest interior avian community of the corridor forests during the 2000 breeding season.

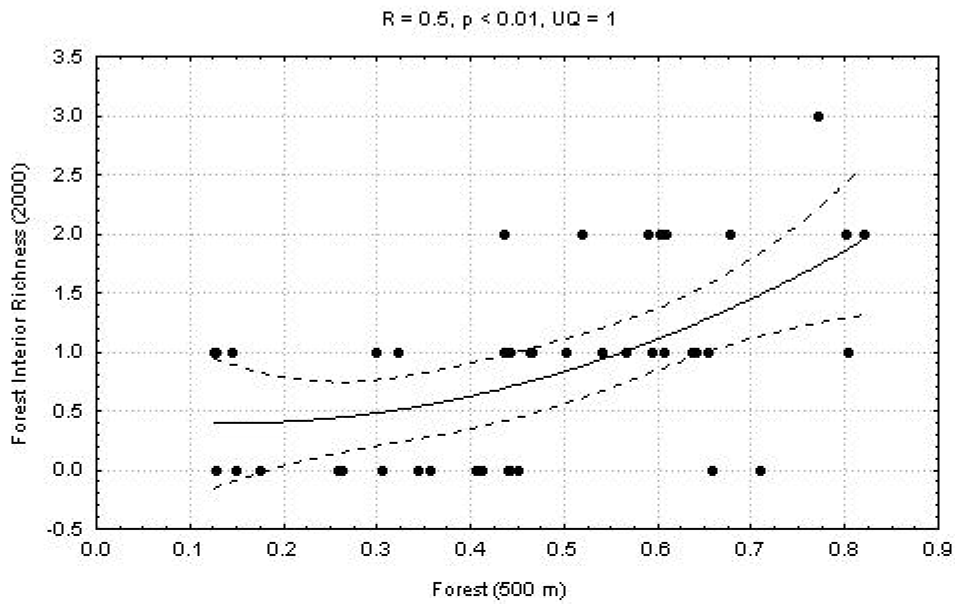
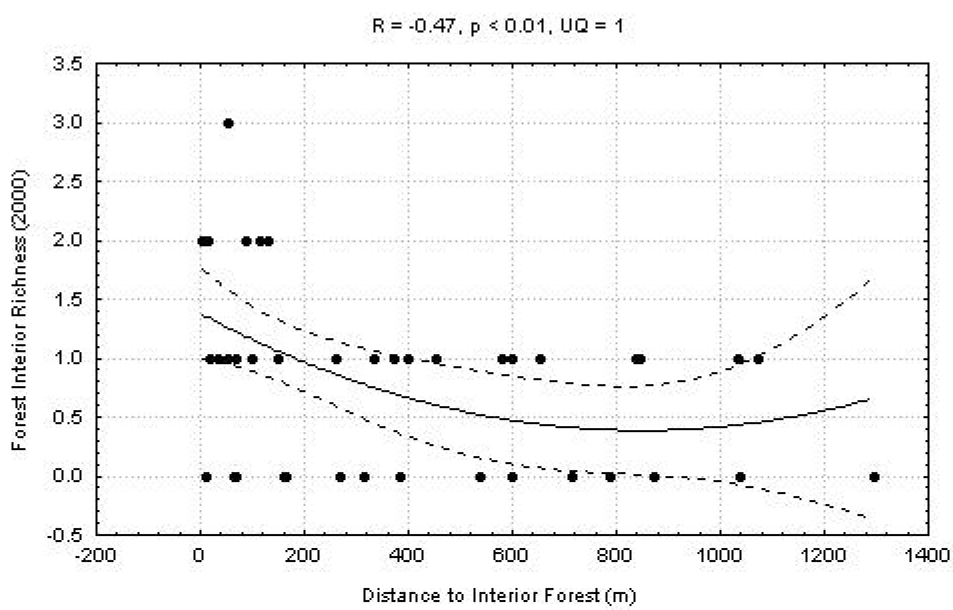


Figure 8-20. Scatterplot and associated thresholds of the relationship between the distance to interior forest and richness for the forest interior avian community of the corridor forests during the 2000 breeding season.



Forest interior species abundance of the corridor forests in the 2000 breeding season had the same factors as was found for the richness of this same community: the amount of forest within 500 m (Figure 8-21) and the distance to interior forest (Figure 8-22). Again, no peak was found in the fitted line (with a maximum of 83%), and the upper quartile threshold (UQ = 1) also occurred above 42%. The results for distance to interior forest with respect to abundance found slightly higher thresholds, with the fitted line finding a threshold at 870 m, and the upper quartile (UQ = 1) below 160 m.

Figure 8-21. Scatterplot and associated thresholds of the relationship between the amount of forest within 500 m and abundance for the forest interior avian community of the corridor forests during the 2000 breeding season.

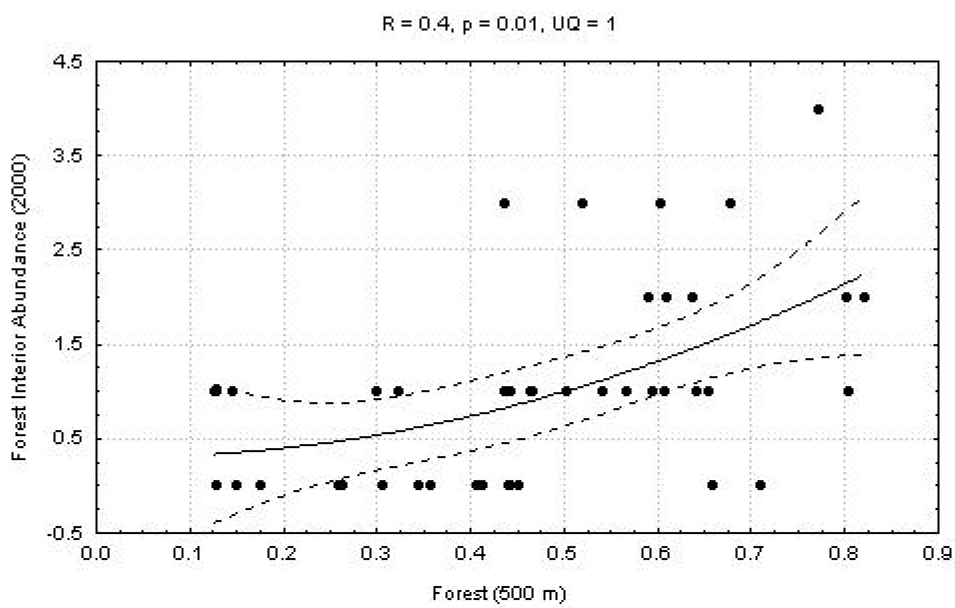
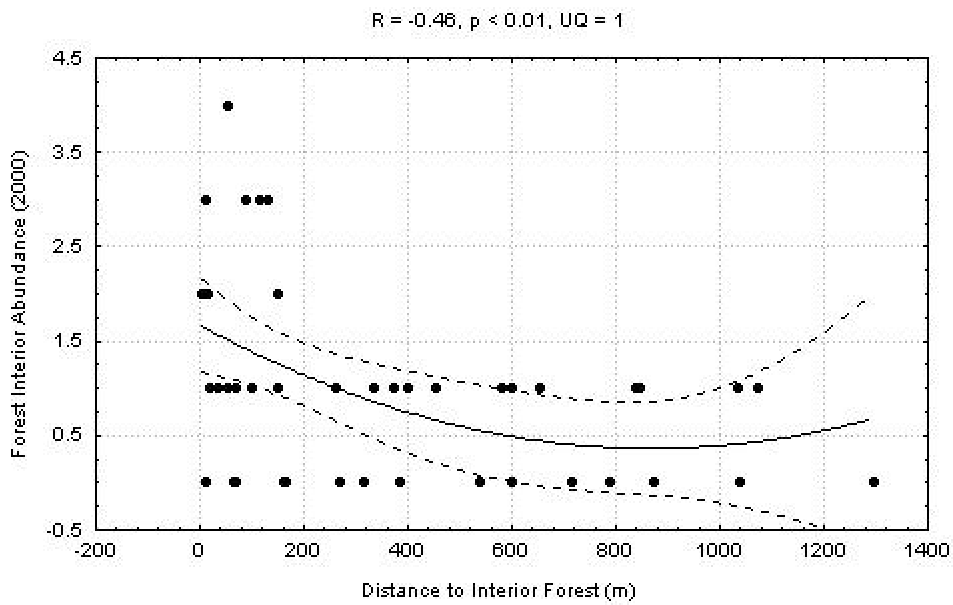


Figure 8-22. Scatterplot and associated thresholds of the relationship between the distance to interior forest and abundance for the forest interior avian community of the corridor forests during the 2000 breeding season.



The forest interior bird community of the patch forests was the only community that had strong correlations with habitat factors; in the 1999 breeding season, both richness and abundance of this community was positively associated strongly with tree density in the Greenbelt. The only other factor with a strong correlation to the forest interior birds of the patch forests was the amount of shrubland within 500 m. Figures 8-23 and 8-24 show the relationship between tree density and forest interior species richness and abundance, respectively. Neither group had a fitted line that showed a threshold in species' responses; the maximum value was 1300 trees per hectare. Both groups also had the same upper quartile threshold (UQ = 2 for both) at 900 stems per acre. In the 2000 breeding season, only forest interior species richness had a strong correlation with any factor, this one a negative one with the amount of shrubland within 500 m (Figure 8-25). The fitted line showed no peak, with the line showing a maximum value at 0%. The upper quartile threshold (UQ = 2) here occurred below 1%.

Figure 8-23. Scatterplot and associated thresholds of the relationship between tree density and richness for the forest interior avian community of the patch forests during the 1999 breeding season.

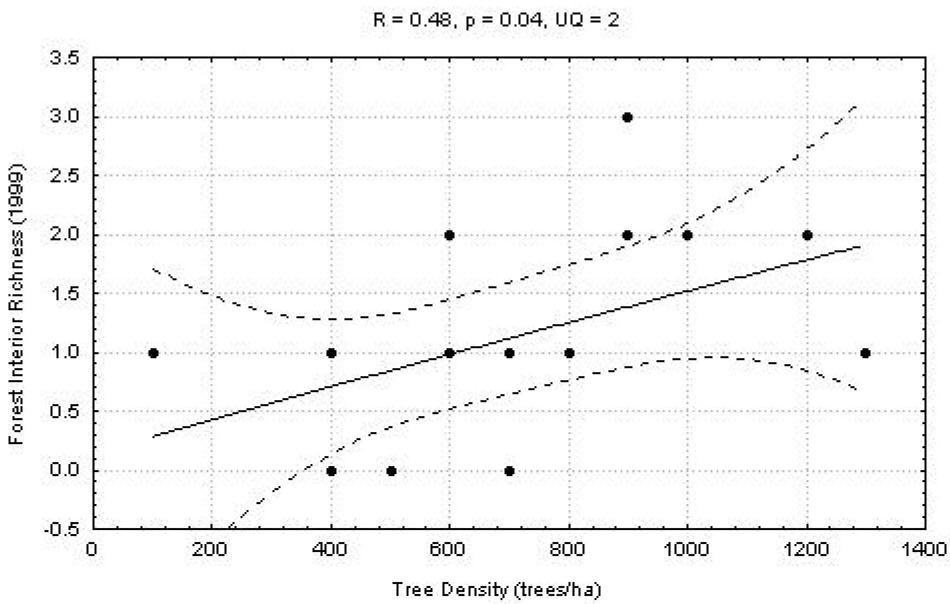


Figure 8-24. Scatterplot and associated thresholds of the relationship between tree density and abundance for the forest interior avian community of the patch forests during the 1999 breeding season.

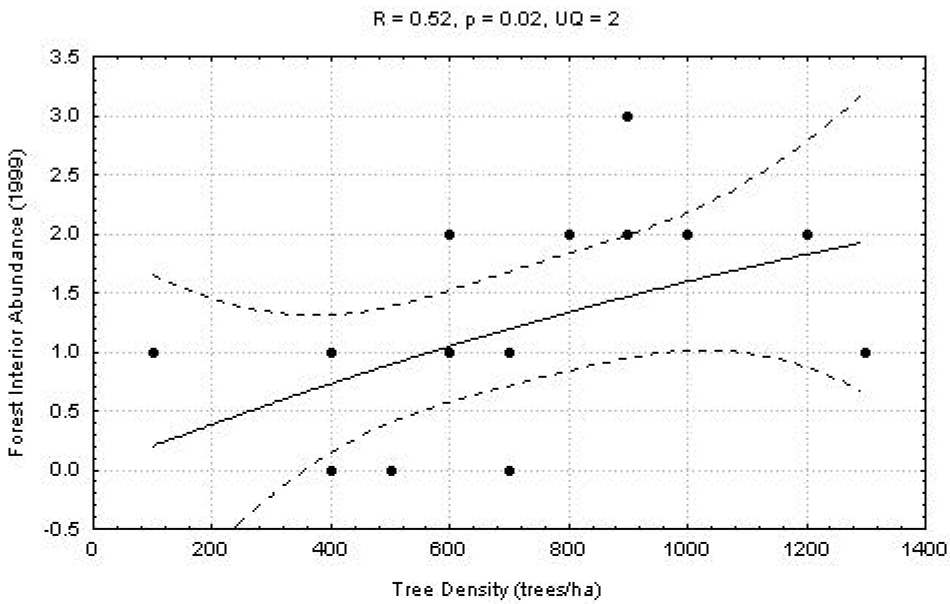
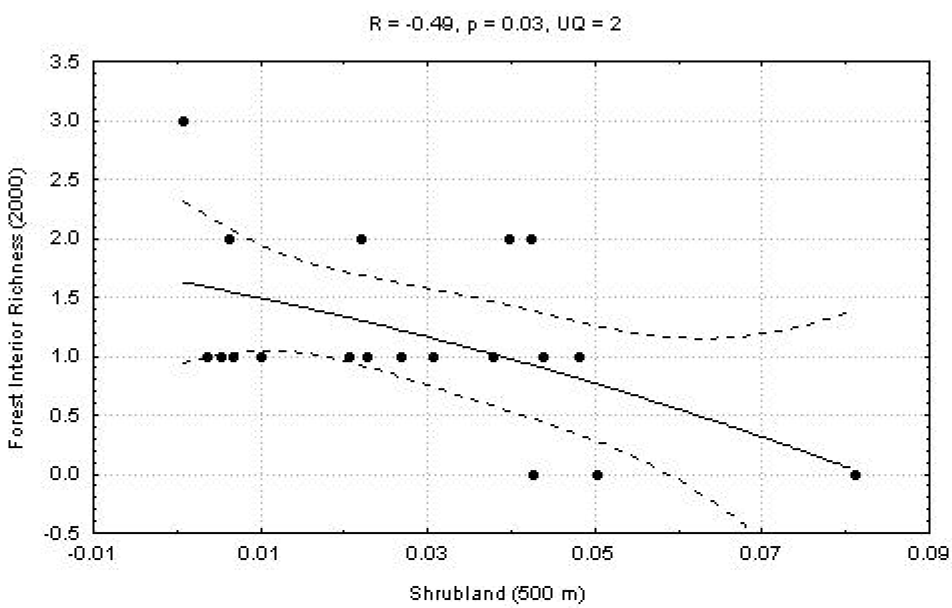


Figure 8-25. Scatterplot and associated thresholds of the relationship between the amount of shrubland within 500 m and richness for the forest interior avian community of the patch forests during the 2000 breeding season.



The potential thresholds for forest interior species richness and abundance in the corridor and patch forests of the Greenbelt for both years are summarized in Table 8-3, and discussed at the end of the chapter.

Table 8-3. Summary of potential thresholds in the forest interior avian community of corridor and patch forests (diagramed in Figures 8-16 through 8-25).

Forest Class, Metric	**Habitat/Landscape Factor**	**Fitted Line Threshold**	**Upper Quartile Threshold**
Corridor, Richness (1999)	Forest Width	250 m	> 220 m
Corridor, Abundance (1999)	Forest Width	250 m	> 210 m
Corridor, Richness (2000)	Forest (500m)	None (83%)	> 42%
Corridor, Richness (2000)	Distance to Interior Forest	830 m	< 140 m
Corridor, Abundance (2000)	Forest (500m)	None (83%)	> 42%
Corridor, Abundance (2000)	Distance to Interior Forest	870 m	< 160 m
Patch, Richness (1999)	Tree Density	None (1300 trees/ha)	> 900 trees/ha
Patch, Abundance (1999)	Tree Density	None (1300 trees/ha)	> 900 trees/ha
Patch, Richness (2000)	Shrubland (500m)	None (0%)	< 1%

Discussion

Of the 25 associations analyzed in this chapter for potential thresholds, 23 were with landscape factors and 2 were with a single habitat factor, tree density. The landscape factors evaluated above include Forest Width, Forest (500 m and 1000 m), Distance to Interior Forest, Shrubland (500 m), Development (1000 m and 2000 m), and Agriculture (100 m and 2000 m). These six factors were consistently and strongly related to a variety of avian communities, both among the overall community as well as within the forest interior community of patches and corridors.

Forest width was one of the major landscape variables under consideration in this study, as several studies in the literature focus on this particular metric as it relates to forest bird species (reviewed in Fischer 1999). In the context of this study, forest width was strongly related to corridor and overall forest interior species richness and abundance in 1999. It was not related to the overall avian community, however. Thresholds in richness and abundance were at 210-250 m for corridor forest interior birds, and between 200-470 m for the overall forest interior bird community. Overall average thresholds were 360 m for the fitted line and 208 m for the upper quartile.

Forest (500 m and 1000 m) was also a major factor under evaluation, as the main avian community of interest—forest interior species—is vitally dependant upon the amount of forest available for the needs of their populations. Six of the twenty five associations were of the amount of forest, which found thresholds ranging from 35% to 83%, depending upon the avian community under consideration, with an overall average of 77% for the fitted line and greater than 37% for the upper quartile. The amount of forest was a significant and strong factor in the overall and the forest interior communities, in both patch and corridor forests, as well as with respect to the forest interior birds across the entire Greenbelt. Clearly, the amount of forest is an important landscape variable to the avian communities of this study as well as to forest avian communities in general; several important studies in the literature bear this out as well (e.g., Whitcomb et al. 1981, Robbins et al. 1989).

Distance to interior forest had a negative relationship with both the forest interior and the overall avian communities, with a total of five associations evaluated in this chapter. Only one association was with the overall bird community, the other four were with the forest interior species. For all birds, the thresholds were less than 840 m and 1240 m; forest interior birds' thresholds were much smaller, ranging from less than 100 m to 870 m, depending upon the community and metric (richness or abundance) under consideration. The upper quartile thresholds were significantly smaller than the fitted line thresholds, with an average value at less than 270 m; the average fitted line threshold was 783 m, reflecting the greater tolerance of the overall avian community for corridor forests.

Agriculture (100 m and 2000 m) had three strong correlations that were evaluated in this chapter, all of them negative, associated with both the overall and forest interior communities. As agriculture significantly simplifies ecosystems, the presence of agriculture would present fewer foraging or other life history opportunities for birds. Thresholds for the amount of agriculture ranged from 0% to less than 50%, with an average threshold of about 5% for the fitted line and less than 43% for the upper quartile.

The amount of development (1000 m and 2000 m) was only associated with the overall avian community—richness in corridor forests, and abundance in patch forests. Regardless, thresholds for development were quite low ranging from 0% to 10%. The average threshold for the upper quartile was less than 4%, with the average fitted line threshold in close agreement at 5%. While development can reduce significantly the amount of forest cover, which could account for its negative relationship with the avian communities of the Greenbelt, it is less damaging than agriculture, and thus of less concern in the short term.

Shrubland (500 m) was the final landscape factor evaluated for thresholds, with abundance of the overall community and richness of the forest interior birds of patch forests. This was the only landscape factor that had a strong correlation with the forest interior community of patch forests. This range of this threshold is small as well, from 0% to 5%. The average thresholds for shrubland were less than 2% for the upper quartile and 2.5% for the fitted line. The reasons for the negative association are probably related to the relative openness of shrubland ecosystems, which would leave forest birds more susceptible to predation.

The only habitat variable evaluated in this chapter—tree density (evaluated as the number of trees per hectare)—was only related with the forest interior birds of the patch forests during 1999. The reason for the relatively high association between these variables is probably related to the types of birds that typically make up the forest interior avian community. These birds are often (but not always) small passerines, who may find plenty of suitable nesting sites, foraging sites, and perching sites, as well as additional cover to protect them from larger predators, in the denser forest areas. However, not all forest interior species prefer dense forests; the Pileated Woodpecker, for example, prefers more open forests with large trees and snags to fulfill its life history requirements. This result, therefore, should be interpreted with caution; dense forests are not good for all forest species all of the time. Obviously, more research is in order before such a claim can be made.

Only five factors were evaluated for patch forests, while ten factors were evaluated for corridor forests and ten for the entire Greenbelt. This supports the idea that the avian species within the patch forests are relatively insulated from landscape-scale effects; this idea is discussed further in the following chapter, along with general conclusions and management recommendations that arise from this study as a whole.

CHAPTER 9

CONCLUSIONS, RECOMMMENDATIONS, AND SUGGESTIONS FOR FURTHER RESEARCH

Conclusions Arising from this Study

The avian community of the Ray Roberts Greenbelt seems to be strongly affected by very few factors that were measured in this study. There are a variety of possible reasons for this, the primary one being the nature of human impacts on regional habitats. Harris and Kangas (1988: 140) make the point that "most faunal assemblages have been impacted by human modification to sufficient extent that the natural relations between floral and faunal assemblages have been nearly obliterated." Andren's (1994) review of fragmentation effects on birds and mammals states that these taxa are primarily affected by habitat factors when suitable habitat makes up more than 30% of the total area of original habitat in a given landscape. When the level of suitable habitat drops below this level, landscape factors—such as the spatial arrangement of habitat patches and other landcover classes—become the dominant factors.

In the context of the Ray Roberts Greenbelt, this makes a great deal of sense: the original extent of the bottomland forest along the Elm Fork of the Trinity was undoubtedly much greater, and was probably connected to a significantly greater degree to the larger bottomland forests of the upper Trinity River system (and thus, one might reasonably presume, with the larger, similar bottomland forests of east Texas). The forest bird community prior to extensive modification and removal by Anglo settlement might have been more diverse and intricately linked with its habitat, while the populations of the remnant forest bird community of today represents the species which could tolerate the amount of disturbance that has occurred over the past 200 years. Some longer lived species with relatively smaller remnant populations—the Pileated Woodpecker, for example—may still be suffering from these effects (either directly, through the amount of available suitable habitat, or indirectly, through inbreeding depression), and may yet be extirpated in the coming years due to impacts to its habitat in prior decades.

The most significant finding of this study was in the comparison of correlations between the birds in patches and those in corridors; species richness and abundance for both the overall community and the forest interior community in corridors was correlated with a variety of landscape factors (most commonly, amount of forest), while those same communities in patch forests were associated with a much smaller array of landscape and habitat factors. Thus, the major implication is that the bird communities of interior forests are somewhat insulated from the effects of the surrounding landscape matrix, and may be affected primarily by factors outside the scope of this study, such as through population factors (e.g., demographics, stochastic events, metapopulation dynamics).

Forest factors were the dominant class of correlations for both the overall and the forest interior avian communities, particularly the amount of forest, the width of the forest, and the distance to the closest area of interior forest. Other classes of landscape variables in the area that showed a relatively strong relationship with the avian communities are usually factors outside of the control of the Corps of Engineers, such as the amount of development or agriculture. The amount of forest can be modified, however, as the soils and ecosystems that are not currently forested within the boundaries of the Greenbelt are amenable to the support of forests. The thresholds for the amount of forest varied from 35% to 90% of a landscape window covered by forest, with the upper quartile of abundance and richness occurring when forests covered at least 35% of the landscape within 1000 m of a point count station. This is remarkably close to the 30% threshold suggested by Andren (1994). Fitted line thresholds usually (with only one exception) did not show a peak, suggesting that bigger is better in terms of the amount of forest available to the avian communities.

The width of the forest was a large factor associated with the avian communities of the Greenbelt, with thresholds ranging from 200 m to 470 m. This is significant in that the minimum threshold found in this study is much larger than any width suggestions usually provided by water quality BMPs (e.g., ~30 m in Oklahoma Cooperative Extension Service [1998]). Interestingly enough, the avian communities of the corridor forests showed a lower threshold in the fitted lines of width to richness and abundance (250 m) than did the communities of the whole Greenbelt (470 m). The upper quartile thresholds were all within 20 m of each other (200-220 m). These figures are all still quite a bit larger than water quality widths, which suggests that where wildlife values are of interest to management, the needs of wildlife (with respect to forest width, at least) should take precedence over water quality issues.

The thresholds associated with the distance to interior forest had a wide range, from a minimum of 100 m to a maximum of 1240 m. This wide range was largely the result of one association, between the abundance of the overall avian community in corridors and distance to interior forest; when considering only the forest interior species, this range dropped to a maximum of 870 m, with an average of ~670 m for the fitted line and 125 m for the upper quartile. Management support for forest interior birds should be conservative, due to the reasons for conservation concern as noted in the introduction of this dissertation, which suggests an average maximum distance of 125 m. Thus, where forest corridors should be created or restored to connect forest patches, efforts should be made to make these corridors as short as possible, while extending the area of the extant patches as much as possible.

A summary of the average thresholds found in this study are presented in Table 9-1. The distance to interior forest factor has been separated by avian community to show the differences when only the forest interior birds are considered.

Table 9-1. Summary of average thresholds in landscape and habitat factors for the avian communities of the Ray Roberts Greenbelt.

Factor	**Average Threshold (Fitted Line)**	**Average Threshold (Upper Quartile)**
Forest	77%	37 %
Forest Width	360 m	208 m
Distance to Interior Forest, Overall	783 m	268 m
Distance to Interior Forest, Forest Interior	669 m	125 m
Agriculture	5%	43%
Development	5%	4%
Shrubland	3%	2%
Tree Density	1300 trees/ha	900 trees/ha

In terms of forest structure and habitat values, an interesting result of this study was that there were no significant differences in the forest across both patches and corridors in terms of habitat structure or vegetation community associations. These results indicate that it may be possible to maintain much of the habitat value present in larger patches along corridors connecting them. Further research on actual patterns of animal usage and movement through the corridors is needed to determine whether the apparent habitat value is truly functional; in the context of this study, habitat value as measured by the three HSI models showed little relationship to the overall or the forest interior avian communities, with no HSI index metric or value strongly correlated with any bird community metric. The only habitat factors strongly correlated with any avian community were the number of forest canopy layers (negative association) and tree density (positive association), both of which are forest phytosociological measures. In other words, the HSI values found in this study were not representative of either the overall or forest interior bird community. Reasons for this could include (Harris and Kangas 1988, O'Neil and Carey 1986, Van Horne 1983):

?? Habitat assessment assumes that "habitat" is an equally useful concept for all species.

?? A species' demographic response to its habitat may not be the same as its response to its niche, that is, habitat assessment cannot account for intracommunity associations.

?? Habitat assessment usually cannot account for spatial and temporal scales involved with the species' life history requirements, particularly for migratory species who are influenced by disparate environments at different stages of their life histories.

?? Habitat association studies for model species may not have accounted for possible variance between density and habitat quality; areas of densest concentrations of individuals do not necessarily mean that these areas are the best habitat.

?? Habitat assessments cannot incorporate important abiotic factors (such as the weather) into assessing potential impacts on species' populations.

?? While the species' limiting factors may be accounted for in habitat assessment, the interactions between such factors may not be well understood, making their assignment in mathematical models arbitrary, at best.

?? Habitat assessment cannot allow for the prediction of stochastic events, which often play an extremely important role in a species' demographic response or in ecosystem process.

?? Habitat assessment cannot distinguish between population "source" and "sink" habitats, which could be the result of factors entirely outside of the elements of habitat measured by HEP.

?? Recent ecological theory suggests that local populations are part of a larger metapopulation, and predicting which local populations are vital and which are not to the continuance of the metapopulation is difficult with current levels of understanding.

?? Habitat assessment assumes that indicator species can predict the occurrence of whole (generic) animal communities.

?? Habitat assessment assumes that a habitat can be assessed independently of its context within the landscape.

While habitat values were similar across the length of the Greenbelt, they did not show any real relationship to the avian communities under consideration in this study. It is possible that the relationships between the birds and their habitat are not strong due to the overriding influence of landscape factors as they have occurred and changed over the past

100 years. The birds that were not extirpated, and thus still remain in the Greenbelt, by these activities may not require a large number or small ranges of habitat variables to fulfill their life history requirements, and instead find much of what they need throughout the forest. Again, population evaluation is the primary way in which such a relationship might be uncovered, and this was not within the scope of this particular project.

The major findings of this study can be summarized as follows:

1. Bird communities in the corridor forests are associated with a greater array of factors than are bird communities in patches, suggesting that the birds of patch forests are somewhat insulated from landscape-scale effects.
2. Habitat values can be maintained in corridors, but there does not seem to be a significant relationship between the bird communities and the habitat.
3. Forest factors are the primary influences (as inferred from the number of associations and the relative strength of these associations) on the bird communities of the Ray Roberts Greenbelt.
4. Thresholds of richness or abundance in the amount of forest as compared with the forest interior bird community suggest that patches are better than corridors to support this community, and that the more interior forest available, the better for forest interior birds. The suggested minimum amount of forest derived from these thresholds is 35% of the amount of forest within 1 kilometer of any given part of the Greenbelt.
5. Thresholds in forest width for avian communities suggest a minimum width of 200 m for any corridor.

6. Thresholds in distance from interior forest suggest that the forest interior bird community can be best supported by shorter corridors that connect larger patches, with a suggested maximum corridor length of 125 m.

Forested Riparian Greenbelt Design Considerations

The literature of conservation biology has a great deal to offer with respect to design considerations for reserves meant to enhance or promote wildlife values, particularly with respect to forested habitats. They are, as follows:

?? Maximize interior forest area. This can be accomplished through restoration that avoids, to the extent possible, dendritic shapes.

?? Minimize human disturbances in the immediate vicinity of the reserve, to allow species sensitive to human activities room to forage and disperse in the absence of potential conflict. Buffer zones can be created through zoning or management in and around the perimeter of a reserve to assist in minimizing human disturbance.

?? Connect currently separated tracts of forest through restoration and the the use of corridors. While some have pointed out a variety of potential problems that may exist with corridors (Simberloff et al. 1992), none of these problems have been recorded in real systems (Beier and Noss 1998).

Management Recommendations

Combining the results of this study with others from the literature leads to a set of management recommendations specific to the Ray Roberts Greenbelt as well as for general consideration in the evaluation and management of other riparian greenbelts in the bottomland hardwoods region of the southeastern United States. It should be noted, however, following the recommendations of Whitcomb et al. (1981: 186) that “the status of bird populations in any forest fragment must be interpreted in a regional context.” Management recommendations that are essential to support forest avifauna in the Ray Roberts Greenbelt may not be relevant in western Mississippi, for example.

The most important factor in breeding habitat is the presence of large, intact tracts of healthy interior forest. This is borne out in the more important papers in the literature (e.g., Whitcomb et al. 1981, Robbins et al. 1989, Conner and Dickson 1997) as well as in this particular study. In the context of riparian greenbelts, where such large, intact forests exist, they should be protected from resource exploitation (e.g., logging) that destroys their integrity. Existing forests should be enhanced where possible by restoration efforts along their edges that minimize edge effects and maximize the extent of interior forest area. The typical small woodlands that are commonly set aside for bird conservation are much too small, and often fail in their role as a reserve, as has been documented in the literature for many years (Whitcomb et al. 1981). Robbins et al. (1989) study on the breeding forest birds of the mid-Atlantic states suggested a minimum reserve area of 3000 ha to protect all forest area sensitive (which would include forest interior species) bird species. While this study did not specifically address the question of forest area on a species by species basis as did Robbins et al. (1989), these results indicate that forest area is extremely important to the avian community of the Ray Roberts Greenbelt, and the positive correlation between forest size and the local avifauna suggest that bigger is indeed better. The largest tract of intact forest within the Greenbelt is a “mere” 94 ha (described in Barry and Kroll 1997, 1999), suggesting that restoration activities are imperative to return these bottomlands to supportive habitat for the majority of its avian breeding residents.

With respect to connectivity, some studies (e.g., Haas 1995, St. Clair et al. 1998) have shown that forest birds forage and disperse preferentially through forest corridors as compared with open areas such as fields or shrublands. Where the support or restoration of large tracts of forest are not possible, and gaps are present between existing tracts of forest, forested corridors should be created that connect these existing tracts of forest. Villard et al. (1995) report a median dispersal distance of 350 m for Neotropical migrant songbirds (many of which are forest interior species), which suggests a maximum corridor distance between intact forests. This research at the Ray Roberts Greenbelt suggests a maximum “optimum” distance between tracts of interior forest of approximately 125 m to support a diverse forest interior avian community; distances larger than that may support individual forest interior birds but may serve as ecological traps or sinks for the population as a whole (Gates and Gysel 1978, Whitaker and Montevecchi 1999). Other sites in the bottomland hardwood region may show different “optima”; however, the distance found in this study is also quite close to the commonly cited extent of major edge effects in forests (Temple 1986), and thus this distance will help minimize the extent of forest affected by edge effects. Where corridors already exist, and the areas around them are not available for restoration, these corridors should be protected as important dispersal habitat.

Additional Considerations and Suggestions for Further Research

The was a fair amount of variation in the avian data sets; unlike, for example, most of the habitat factors measured in this study (such as tree density), birds can be readily overlooked—and thus not counted—in forests if they remain still and quiet during the duration of a given station's sampling period. The ability to sample the same station several times a season would be ideal, which would minimize the types of errors that could arise from failing to detect birds that were present but not counted. This study, due to logistical constraints, was only able to sample each station once per season. Where time and resources permit, other studies of this type should attempt to sample the same station numerous times.

Evaluations of entire communities often show a great deal of variation because communities are human categorical constructs (Allen and Hoekstra 1992) that may not accurately represent how these species individually react to landscape and habitat factors. Different forest interior bird species, for example, react differently to the same habitat variables. Some species may prefer a more open understory with a predominance of large trees and snags (such as the Pileated Woodpecker), while others may prefer a relatively denser understory in which to hide from and avoid predators (such as the Prothonotary Warbler). Thus, an evaluation of each species' response to landscape and habitat variables can be quite useful in illuminating relationships that were not apparent in a community-wide analysis. The research team involved with this study will continue to explore these potential relationships; they are, however, not a specific part of the study discussed in this dissertation, and therefore are not discussed herein.

Robbins et al. (1989) suggestion of a minimum reserve area of 3000 ha to protect all forest area sensitive bird species bears further investigation. Future studies of the forest avifauna of the Ray Roberts Greenbelt and other bottomland hardwood forest sites might consider exploring species-area curves and the use of logistic regression to address the question of forest area on a species by species basis, to help determine minimum area thresholds for particularly important species, such as threatened, endangered, Partners in Flight priority, or management sensitive species.

Connectivity and dispersal characteristics of many bird species are not well known (Freemark et al. 1995), and future studies might consider comparing dispersal through forests as compared with adjacent open lands, as was done in St. Clair et al. (1998).

Concluding Thought

Conner and Dickson (1997) note that the forest interior birds are of the most concern to management in forested regions due to a variety of reasons, most significantly from the loss and fragmentation of previously forested areas. If these declining species are to be conserved in their breeding ranges, efforts must be made to support them to the greatest extent possible. The most useful way to do this is through forest restoration efforts that are aimed at alleviating the effects of fragmentation, through the creation of larger patches of forest, with corridors connecting these patches that are of suitable width and length.

APPENDIX

Point Count Data for Avian, Landscape, and Habitat Variables at Each Station

PCS	WEST	NORTH	CLASS	RICH99	DENS99	FORICH99	FODENS99	RICH00	DENS00	FORICH00	FODENS00	SUCCSTG	WIDTH	TOEDGE	TOINTFO	INTFOARA	CANCOV	CI	FHD	BROW HSI	PIWO HSI	HAWO HSI	NRPRICH99
1	682928	3692044	Corridor	3	4	1	1	6	12	0	0	UR	95	40	1295	0	0.90	2.50	0.42	0.92	0.00	0.71	0
2	683032	3691807	Corridor	4	5	0	0	7	8	1	1	SE	50	15	1035	0	0.95	3.72	0.39	0.55	0.00	0.59	0
3	683061	3691564	Corridor	8	15	0	0	8	13	0	0	UR	125	75	790	0	0.80	16.07	0.52	0.77	0.00	0.71	1
4	683154	3691367	Corridor	9	12	0	0	6	9	1	1	SE	75	10	580	0	0.80	1.49	0.30	0.55	0.00	0.17	0
5	683291	3691141	Corridor	7	15	0	0	8	13	1	1	UR	85	30	335	0	0.65	3.60	0.46	1.00	0.32	0.70	0
6	683274	3690921	Corridor	7	11	0	0	7	12	2	3	UR	155	55	115	0	0.75	1.55	0.34	0.77	0.00	0.54	0
7	683277	3690731	Corridor	9	13	1	1	12	21	2	2	OG	180	80	10	0	0.75	8.67	0.42	0.97	0.72	0.85	1
8	683259	3690508	Corridor	9	12	0	0	5	7	1	1	UR	125	45	150	0	0.65	1.88	0.42	0.84	0.00	0.53	1
9	683362	3690279	Patch	7	9	1	1	5	7	1	1	UR	245	115	0	4553	0.75	2.77	0.53	0.84	0.00	0.85	0
10	683289	3690033	Corridor	6	7	0	0	6	12	0	0	SE	165	70	160	0	0.65	9.65	0.43	0.67	0.34	0.64	0
11	683468	3689868	Patch	11	19	1	2	9	15	2	2	UR	255	115	0	199621	0.80	10.78	0.37	0.84	0.39	0.95	1
12	683708	3689720	Patch	5	10	1	1	7	12	0	0	SE	285	105	0	199621	0.85	2.97	0.44	0.39	0.00	0.17	0
13	683712	3689473	Patch	11	18	2	2	9	15	1	1	UR	295	115	0	199621	0.75	9.31	0.49	0.67	0.00	0.78	2
14	683715	3689188	Patch	7	13	1	1	11	15	2	3	SI	320	135	0	199621	0.95	0.00	0.28	0.00	0.00	0.00	0
15	683690	3688926	Patch	4	6	0	0	7	12	0	0	UR	290	130	0	199621	0.85	9.13	0.44	0.77	0.30	0.95	0
16	683671	3688716	Corridor	6	9	1	1	9	16	2	3	UR	90	10	90	0	0.35	3.29	0.50	0.30	0.13	0.30	0
17	683704	3688503	Corridor	6	9	1	1	8	14	1	1	SE	80	10	100	0	0.85	1.64	0.48	0.00	0.00	0.87	0
18	683615	3688260	Corridor	4	9	0	0	7	15	0	0	SE	205	80	10	0	0.55	0.37	0.42	0.00	0.00	0.00	0
19	683353	3688261	Corridor	8	14	1	1	11	18	1	1	UR	170	75	35	0	0.60	1.13	0.50	0.88	0.00	0.65	0
20	683068	3688189	Corridor	8	11	1	1	7	10	1	1	UR	180	85	20	0	0.55	1.53	0.50	0.60	0.00	0.60	0
21	683043	3687964	Corridor	8	10	1	1	7	11	0	0	UR	75	15	165	0	0.60	8.49	0.47	0.88	0.00	0.65	1
22	682865	3687781	Corridor	7	9	0	0	7	9	0	0	OG	80	20	385	0	0.80	16.64	0.47	0.97	0.27	0.95	0
23	682617	3687692	Corridor	7	11	0	0	4	7	1	1	UR	70	20	600	0	0.85	12.72	0.49	0.97	0.00	0.71	1
24	682422	3687549	Corridor	7	7	0	0	7	10	1	1	UR	75	20	845	0	0.80	2.95	0.30	0.55	0.00	0.17	0
25	682393	3687306	Corridor	6	9	0	0	6	12	0	0	OG	90	30	1040	0	0.60	22.91	0.40	0.95	0.46	0.65	0
26	682296	3687082	Corridor	4	6	0	0	6	6	1	1	UR	80	20	1075	0	0.65	10.19	0.56	0.77	0.14	0.70	1
27	682263	3686837	Corridor	5	8	1	1	5	9	0	0	UR	185	80	875	0	0.85	7.57	0.28	0.84	0.00	0.95	1
28	682188	3686604	Corridor	6	12	0	0	7	11	0	0	UR	120	55	715	0	0.55	5.61	0.28	0.75	0.12	0.60	0
29	682191	3686364	Corridor	7	8	0	0	8	14	0	0	UR	90	20	540	0	0.75	2.50	0.46	0.92	0.00	0.85	0
30	682352	3686118	Corridor	6	6	0	0	8	18	0	0	UR	95	20	270	0	0.75	0.28	0.53	0.84	0.00	0.85	0
31	682570	3686112	Corridor	9	11	1	1	9	16	0	0	SE	150	40	70	0	0.80	2.68	0.33	0.00	0.00	0.62	0
32	682726	3685930	Patch	10	15	2	2	8	13	1	2	SE	435	210	0	87735	0.85	2.62	0.51	0.00	0.00	0.00	2
33	682820	3685696	Corridor	6	9	2	2	3	6	1	1	SI	215	25	70	0	0.70	0.33	0.33	0.00	0.00	0.00	0
34	682823	3685450	Corridor	8	10	0	0	7	11	0	0	UR	110	35	315	0	0.75	11.40	0.39	0.92	0.00	0.85	0
35	682827	3685207	Corridor	8	11	0	0	10	13	1	1	UR	120	60	455	0	0.75	5.98	0.43	0.55	0.00	0.85	1
36	682809	3684954	Corridor	8	12	0	0	7	12	1	1	UR	90	35	260	0	0.70	17.77	0.44	0.97	0.00	0.80	1
37	682922	3684715	Corridor	11	14	3	4	9	16	2	3	OG	220	90	10	0	0.90	6.77	0.30	1.00	0.00	0.95	1
38	682703	3684602	Patch	6	9	0	0	9	15	0	0	UR	415	180	0	665522	0.85	1.07	0.52	0.67	0.00	0.95	0
39	682490	3684542	Patch	7	15	2	2	7	11	1	1	UR	505	215	0	665522	0.70	8.30	0.41	0.00	0.00	0.80	2
40	682257	3684482	Patch	8	10	0	0	11	21	1	1	UR	595	285	0	665522	0.70	2.61	0.47	0.67	0.18	0.80	0
41	682072	3684296	Patch	6	10	1	1	10	17	1	1	UR	665	330	0	665522	0.50	5.41	0.42	0.74	0.12	0.50	0
42	681985	3684057	Patch	7	10	0	0	7	14	1	1	UR	580	290	0	665522	0.70	2.51	0.29	0.67	0.00	0.73	0
43	681945	3683824	Patch	10	18	1	1	7	16	1	1	UR	480	230	0	665522	0.75	6.22	0.41	0.59	0.00	0.85	0
44	681898	3683545	Corridor	8	15	0	0	9	16	2	2	UR	385	90	5	0	0.75	1.90	0.38	0.77	0.00	0.85	0
45	681779	3683319	Corridor	7	10	0	0	10	17	1	2	UR	85	45	150	0	0.75	0.81	0.20	0.67	0.00	0.78	0
46	681714	3683080	Corridor	7	10	0	0	8	15	1	1	UR	65	30	400	0	0.60	3.43	0.32	0.79	0.00	0.49	1
47	681739	3682814	Corridor	6	9	0	0	9	14	1	1	UR	80	45	655	0	0.75	10.44	0.46	0.92	0.17	0.85	0
48	681772	3682548	Corridor	8	9	0	0	13	20	1	1	SE	55	20	840	0	0.70	3.50	0.45	0.00	0.00	0.28	0
49	681764	3682298	Corridor	7	8	1	1	8	14	0	0	SE	120	35	600	0	0.80	6.32	0.42	0.00	0.00	0.24	0
50	681797	3682046	Corridor	5	8	0	0	10	14	1	1	UR	105	45	375	0	0.90	6.54	0.39	0.97	0.19	0.95	0
51	681953	3681859	Corridor	8	9	0	0	9	18	2	3	SE	140	45	130	0	0.85	12.24	0.38	1.00	0.00	0.95	0
52	682176	3681763	Patch	9	10	1	1	9	15	3	3	UR	270	135	0	226659	0.75	14.96	0.47	0.77	0.00	0.85	0
53	682416	3681696	Corridor	7	12	1	1	11	17	2	2	UR	250	80	15	0	0.80	2.06	0.49	0.92	0.00	0.95	2
54	682271	3681505	Corridor	7	9	3	3	5	9	0	0	UR	300	45	65	0	0.75	13.18	0.34	0.77	0.00	0.85	1
55	682246	3681261	Patch	6	9	1	1	8	17	2	4	SE	385	140	0	226659	0.75	13.83	0.61	0.00	0.00	0.00	1
56	682123	3681043	Patch	9	10	3	3	8	16	1	1	UR	440	155	0	226659	0.75	16.54	0.49	0.92	0.34	0.85	0
57	682128	3680733	Corridor	7	12	1	1	8	18	3	4	SI	150	50	55	0	0.30	0.96	0.40	0.00	0.00	0.00	0
58	682252	3680485	Corridor	4	6	0	0	6	9	1	1	UR	215	45	55	0	0.85	6.25	0.39	0.92	0.33	0.95	0
59	682318	3680252	Corridor	5	8	0	0	9	17	2	2	SE	425	90	10	0	0.80	4.02	0.48	0.45	0.00	0.67	1
60	682239	3679991	Patch	1	1	0	0	6	11	1	1	UR	450	155	0	322418	0.85	7.13	0.34	0.77	0.42	0.95	0
61	682216	3679757	Patch	9	11	2	2	13	17	1	2	UR	670	300	0	322418	0.75	2.20	0.37	0.67	0.75	0.85	1
62	682199	3679522	Patch	6	8	2	2	7	12	2	2	UR	685	220	0	322418	0.75	17.10	0.43	0.53	0.85	0.85	0

Point Count Data for Avian, Landscape, and Habitat Variables at Each Station

NRPDENS99	NRPRICH00	NRPDENS00	BIGTREES	MEANDBH	BIGSNAGS	DEADFALL	TREEDOM	TREEDENS	CANLAYRS	TREERICH	SNAGDOM	SNAGDENS	AGR100	DEV100	FOR100	RAN100	SHR100	WAT100	AGR500
0	0	0	5	45	0	1	83	300	5	2	0.00	0	0.06	0.00	0.80	0.12	0.02	0.00	0.10
0	0	0	2	25	1	6	28	1100	4	3	0.00	0	0.05	0.00	0.63	0.14	0.11	0.06	0.16
1	0	0	3	40	0	2	115	700	5	4	0.17	100	0.00	0.00	0.87	0.00	0.11	0.03	0.22
0	1	1	5	25	0	3	31	600	4	2	0.00	0	0.00	0.00	0.71	0.03	0.26	0.00	0.28
0	0	0	8	55	2	6	48	500	5	3	0.00	0	0.01	0.02	0.77	0.11	0.09	0.00	0.27
0	0	0	5	35	0	3	48	400	4	2	0.00	0	0.00	0.00	0.98	0.00	0.02	0.00	0.23
1	1	1	19	50	2	9	87	500	5	4	0.10	200	0.05	0.00	0.88	0.00	0.07	0.00	0.28
1	0	0	6	40	0	5	29	400	4	4	0.02	100	0.13	0.00	0.76	0.00	0.09	0.02	0.39
0	0	0	7	40	2	7	69	400	5	2	0.00	0	0.01	0.00	0.99	0.00	0.00	0.00	0.40
0	0	0	8	30	2	7	80	800	5	3	0.07	100	0.19	0.00	0.77	0.00	0.03	0.00	0.47
2	0	0	7	45	3	11	84	800	4	4	0.02	100	0.00	0.00	1.00	0.00	0.00	0.00	0.38
0	0	0	1	25	0	4	53	700	4	2	0.00	0	0.00	0.00	1.00	0.00	0.00	0.00	0.35
2	1	1	2	30	1	6	39	1200	5	4	0.02	100	0.00	0.00	0.98	0.00	0.00	0.02	0.44
0	0	0	0	8	0	0	1	100	3	1	0.00	0	0.00	0.00	0.97	0.00	0.00	0.03	0.41
0	0	0	7	35	2	5	73	500	5	5	0.00	0	0.00	0.00	1.00	0.00	0.00	0.00	0.47
0	0	0	7	55	3	5	76	300	5	3	0.31	100	0.11	0.00	0.80	0.02	0.07	0.00	0.51
0	0	0	0	30	1	2	33	500	5	2	0.03	100	0.28	0.00	0.58	0.00	0.14	0.00	0.47
0	1	1	0	20	0	2	8	400	4	3	0.00	0	0.00	0.00	0.94	0.00	0.05	0.00	0.37
0	0	0	4	45	1	2	71	400	4	1	0.00	0	0.12	0.00	0.83	0.00	0.05	0.00	0.46
0	0	0	6	30	2	10	38	500	4	2	0.00	0	0.03	0.00	0.86	0.00	0.09	0.02	0.59
1	0	0	8	45	1	2	94	600	5	3	0.00	0	0.37	0.02	0.61	0.00	0.00	0.00	0.63
0	1	1	7	50	2	3	119	700	5	4	0.09	100	0.44	0.00	0.53	0.00	0.03	0.00	0.81
1	0	0	4	50	0	1	170	500	5	3	0.00	0	0.53	0.00	0.36	0.00	0.10	0.02	0.84
0	0	0	3	25	0	4	46	400	4	4	0.03	100	0.48	0.00	0.42	0.00	0.10	0.00	0.85
0	0	0	11	60	4	11	153	1000	5	3	0.52	400	0.49	0.00	0.51	0.00	0.00	0.00	0.80
1	0	0	5	35	1	3	73	700	5	4	0.00	0	0.54	0.12	0.26	0.00	0.08	0.00	0.76
3	0	0	7	40	1	9	63	600	4	5	0.00	0	0.12	0.01	0.78	0.05	0.03	0.01	0.73
0	0	0	4	40	1	3	52	900	3	4	0.00	0	0.16	0.00	0.66	0.00	0.18	0.00	0.67
0	1	1	3	45	1	4	42	400	5	3	0.00	0	0.11	0.00	0.72	0.03	0.15	0.00	0.65
0	0	0	5	40	1	2	17	200	4	2	0.00	0	0.30	0.00	0.61	0.00	0.08	0.00	0.60
0	1	1	0	25	1	7	50	600	3	3	0.02	100	0.32	0.00	0.56	0.00	0.12	0.00	0.56
2	0	0	0	20	0	2	36	900	4	2	0.00	0	0.00	0.00	1.00	0.00	0.00	0.00	0.53
0	0	0	0	13	0	0	7	400	4	3	0.01	100	0.12	0.02	0.86	0.00	0.00	0.00	0.45
0	0	0	3	45	1	5	76	600	5	5	0.02	100	0.35	0.00	0.57	0.00	0.07	0.00	0.44
1	0	0	1	35	2	7	62	600	4	4	0.01	100	0.15	0.00	0.80	0.00	0.05	0.00	0.49
1	0	0	11	50	3	6	222	1000	4	2	0.01	100	0.18	0.00	0.69	0.00	0.12	0.00	0.28
1	0	0	15	60	4	6	90	500	5	3	0.10	100	0.00	0.00	0.97	0.00	0.03	0.00	0.15
0	0	0	2	30	2	5	34	400	4	2	0.00	0	0.00	0.00	1.00	0.00	0.00	0.00	0.22
6	0	0	0	35	2	7	52	1000	4	4	0.03	200	0.00	0.00	1.00	0.00	0.00	0.00	0.25
0	1	1	4	30	2	6	81	400	4	2	0.00	0	0.00	0.00	1.00	0.00	0.00	0.00	0.20
0	2	3	5	45	2	4	48	700	4	4	0.35	300	0.00	0.00	1.00	0.00	0.00	0.00	0.08
0	0	0	3	30	1	9	40	700	3	3	0.05	200	0.00	0.00	1.00	0.00	0.00	0.00	0.14
0	0	0	1	40	3	5	44	700	4	5	0.00	0	0.00	0.00	1.00	0.00	0.00	0.00	0.22
0	0	0	7	35	1	4	38	500	5	2	0.00	0	0.00	0.00	0.97	0.00	0.00	0.03	0.23
0	1	1	3	30	1	2	40	500	4	1	0.00	0	0.04	0.00	0.80	0.02	0.02	0.12	0.13
1	1	1	5	40	0	3	57	400	5	3	0.01	100	0.00	0.00	0.90	0.07	0.00	0.03	0.05
0	0	0	4	45	2	5	77	900	5	3	0.18	200	0.00	0.00	0.91	0.07	0.00	0.02	0.00
0	0	0	0	20	1	1	25	700	5	4	0.15	100	0.00	0.00	0.84	0.16	0.00	0.00	0.00
0	1	1	0	15	1	6	21	1200	5	5	0.11	600	0.00	0.00	0.91	0.05	0.00	0.03	0.00
0	0	0	5	50	2	7	109	400	5	3	0.65	100	0.00	0.00	0.93	0.05	0.01	0.02	0.00
0	0	0	16	55	1	9	102	600	5	4	0.04	100	0.00	0.00	0.97	0.01	0.00	0.02	0.00
0	0	0	3	35	2	2	125	600	5	4	0.96	100	0.00	0.00	1.00	0.00	0.00	0.00	0.00
2	1	1	8	45	1	5	46	300	5	3	0.00	0	0.00	0.00	0.93	0.03	0.00	0.04	0.00
1	0	0	10	35	1	3	73	900	5	4	0.00	0	0.00	0.00	0.99	0.00	0.00	0.01	0.00
1	1	1	0	20	0	4	35	1300	6	5	0.10	600	0.00	0.00	0.92	0.05	0.00	0.03	0.00
0	1	4	8	45	1	5	92	900	5	4	0.00	0	0.00	0.00	0.97	0.00	0.00	0.03	0.04
0	1	4	0	15	0	5	17	700	4	2	0.00	0	0.00	0.17	0.66	0.02	0.02	0.14	0.03
0	1	1	8	45	2	4	42	600	5	5	0.00	0	0.00	0.00	0.89	0.09	0.00	0.02	0.00
2	1	2	2	20	3	4	27	1000	5	3	0.00	0	0.00	0.00	0.97	0.00	0.00	0.03	0.00
0	0	0	15	35	2	2	51	700	5	4	0.00	0	0.00	0.00	0.98	0.00	0.00	0.02	0.01
1	1	1	20	30	12	16	24	600	5	3	0.00	0	0.00	0.00	0.93	0.07	0.00	0.00	0.06
0	0	0	13	35	17	7	143	600	5	4	0.00	0	0.00	0.00	0.98	0.00	0.00	0.02	0.07

DEV500	FOR500	RAN500	SHR500	WAT500	AGR1000	DEV1000	FOR1000	RAN1000	SHR1000	WAT1000	AGR2000	DEV2000	FOR2000	RAN2000	SHR2000	WAT2000
0.14	0.35	0.33	0.08	0.00	0.12	0.17	0.33	0.23	0.07	0.08	0.16	0.10	0.30	0.13	0.06	0.24
0.01	0.44	0.29	0.10	0.01	0.13	0.13	0.40	0.25	0.08	0.01	0.18	0.10	0.33	0.15	0.07	0.17
0.00	0.41	0.25	0.11	0.01	0.14	0.06	0.44	0.26	0.10	0.00	0.21	0.10	0.35	0.16	0.07	0.11
0.00	0.44	0.17	0.11	0.00	0.16	0.02	0.48	0.23	0.11	0.00	0.24	0.10	0.37	0.16	0.07	0.07
0.00	0.57	0.06	0.10	0.00	0.23	0.01	0.49	0.17	0.10	0.00	0.27	0.09	0.38	0.16	0.07	0.03
0.00	0.60	0.04	0.11	0.01	0.27	0.01	0.49	0.14	0.09	0.01	0.29	0.08	0.38	0.16	0.07	0.01
0.01	0.59	0.02	0.09	0.01	0.29	0.01	0.49	0.11	0.09	0.01	0.32	0.06	0.39	0.16	0.07	0.00
0.00	0.50	0.02	0.07	0.01	0.30	0.00	0.50	0.10	0.09	0.01	0.35	0.03	0.39	0.15	0.07	0.00
0.00	0.50	0.04	0.05	0.01	0.38	0.00	0.48	0.06	0.07	0.01	0.36	0.02	0.41	0.14	0.07	0.00
0.00	0.44	0.04	0.04	0.00	0.40	0.00	0.44	0.08	0.07	0.01	0.38	0.01	0.40	0.12	0.08	0.00
0.00	0.53	0.04	0.04	0.01	0.48	0.00	0.41	0.05	0.06	0.01	0.37	0.02	0.43	0.11	0.07	0.00
0.00	0.55	0.04	0.05	0.01	0.53	0.00	0.40	0.02	0.04	0.00	0.35	0.03	0.44	0.10	0.07	0.00
0.00	0.53	0.00	0.03	0.00	0.56	0.00	0.36	0.02	0.04	0.00	0.38	0.04	0.43	0.09	0.07	0.00
0.00	0.54	0.00	0.04	0.00	0.54	0.00	0.38	0.02	0.05	0.00	0.41	0.04	0.41	0.08	0.06	0.00
0.00	0.48	0.00	0.04	0.00	0.51	0.02	0.41	0.01	0.05	0.00	0.45	0.04	0.37	0.07	0.06	0.00
0.00	0.44	0.00	0.04	0.00	0.48	0.06	0.40	0.01	0.05	0.00	0.47	0.05	0.35	0.07	0.05	0.00
0.01	0.47	0.00	0.05	0.00	0.45	0.07	0.41	0.01	0.05	0.00	0.48	0.05	0.33	0.08	0.05	0.00
0.12	0.44	0.00	0.06	0.00	0.48	0.08	0.37	0.02	0.05	0.01	0.50	0.05	0.31	0.08	0.05	0.00
0.05	0.44	0.01	0.05	0.00	0.52	0.07	0.35	0.01	0.05	0.01	0.51	0.05	0.30	0.08	0.05	0.00
0.03	0.32	0.00	0.04	0.02	0.56	0.05	0.32	0.01	0.05	0.01	0.52	0.06	0.28	0.08	0.05	0.00
0.05	0.26	0.00	0.04	0.02	0.61	0.06	0.29	0.01	0.04	0.01	0.53	0.06	0.28	0.07	0.05	0.00
0.01	0.15	0.00	0.01	0.02	0.69	0.05	0.23	0.00	0.03	0.01	0.54	0.07	0.27	0.07	0.05	0.00
0.00	0.13	0.00	0.02	0.01	0.76	0.03	0.16	0.01	0.02	0.01	0.57	0.08	0.24	0.07	0.04	0.00
0.00	0.13	0.00	0.02	0.01	0.83	0.03	0.10	0.02	0.02	0.01	0.59	0.09	0.22	0.06	0.04	0.00
0.03	0.13	0.02	0.02	0.00	0.82	0.04	0.10	0.01	0.02	0.01	0.60	0.08	0.22	0.05	0.04	0.00
0.03	0.15	0.04	0.02	0.00	0.80	0.05	0.12	0.01	0.02	0.00	0.62	0.08	0.21	0.05	0.04	0.00
0.03	0.17	0.03	0.04	0.00	0.76	0.05	0.16	0.01	0.02	0.00	0.63	0.08	0.20	0.05	0.03	0.00
0.02	0.26	0.01	0.04	0.00	0.73	0.05	0.18	0.01	0.02	0.00	0.63	0.08	0.20	0.06	0.03	0.00
0.00	0.31	0.00	0.04	0.00	0.72	0.05	0.20	0.01	0.02	0.00	0.60	0.08	0.22	0.06	0.03	0.00
0.00	0.36	0.00	0.04	0.00	0.72	0.04	0.21	0.00	0.03	0.00	0.56	0.07	0.28	0.06	0.03	0.00
0.00	0.41	0.00	0.03	0.00	0.72	0.03	0.22	0.00	0.03	0.00	0.53	0.06	0.32	0.05	0.04	0.00
0.01	0.43	0.00	0.03	0.00	0.69	0.04	0.24	0.01	0.02	0.00	0.49	0.06	0.35	0.05	0.04	0.00
0.03	0.46	0.00	0.05	0.00	0.61	0.02	0.30	0.01	0.05	0.00	0.46	0.06	0.38	0.05	0.04	0.00
0.03	0.45	0.01	0.07	0.00	0.52	0.02	0.38	0.02	0.06	0.00	0.44	0.06	0.40	0.05	0.04	0.00
0.03	0.30	0.02	0.17	0.00	0.43	0.02	0.46	0.02	0.07	0.00	0.42	0.06	0.41	0.06	0.04	0.00
0.00	0.54	0.03	0.14	0.00	0.40	0.02	0.50	0.02	0.07	0.00	0.40	0.06	0.42	0.07	0.04	0.00
0.00	0.68	0.04	0.12	0.00	0.35	0.03	0.53	0.02	0.07	0.00	0.37	0.06	0.44	0.08	0.04	0.00
0.00	0.68	0.01	0.08	0.01	0.32	0.01	0.46	0.16	0.06	0.00	0.37	0.06	0.43	0.09	0.04	0.00
0.00	0.70	0.00	0.04	0.00	0.42	0.00	0.51	0.02	0.05	0.00	0.38	0.05	0.42	0.10	0.04	0.00
0.00	0.79	0.00	0.01	0.00	0.46	0.01	0.46	0.02	0.04	0.00	0.38	0.05	0.41	0.10	0.05	0.00
0.00	0.91	0.00	0.01	0.00	0.47	0.01	0.44	0.03	0.04	0.00	0.36	0.05	0.44	0.11	0.04	0.00
0.00	0.83	0.02	0.01	0.00	0.43	0.01	0.47	0.05	0.03	0.00	0.33	0.04	0.46	0.12	0.04	0.00
0.00	0.71	0.07	0.00	0.00	0.38	0.01	0.50	0.08	0.03	0.00	0.31	0.03	0.47	0.15	0.04	0.00
0.00	0.61	0.15	0.00	0.01	0.31	0.00	0.50	0.15	0.02	0.00	0.27	0.02	0.50	0.17	0.04	0.00
0.00	0.64	0.21	0.01	0.01	0.25	0.00	0.53	0.19	0.03	0.00	0.24	0.02	0.52	0.18	0.04	0.00
0.00	0.65	0.28	0.00	0.01	0.20	0.00	0.57	0.20	0.02	0.00	0.21	0.02	0.54	0.19	0.04	0.00
0.00	0.59	0.40	0.00	0.01	0.12	0.00	0.61	0.25	0.01	0.00	0.18	0.01	0.56	0.20	0.04	0.00
0.00	0.64	0.35	0.00	0.00	0.04	0.00	0.65	0.30	0.01	0.00	0.18	0.02	0.56	0.21	0.04	0.00
0.00	0.66	0.34	0.00	0.00	0.00	0.00	0.67	0.32	0.00	0.00	0.17	0.02	0.55	0.21	0.05	0.00
0.00	0.61	0.39	0.00	0.00	0.01	0.00	0.67	0.31	0.01	0.00	0.16	0.03	0.55	0.22	0.04	0.00
0.00	0.52	0.47	0.00	0.01	0.02	0.00	0.68	0.29	0.01	0.00	0.14	0.03	0.56	0.23	0.04	0.00
0.00	0.62	0.37	0.00	0.00	0.01	0.01	0.68	0.29	0.01	0.00	0.11	0.03	0.58	0.25	0.03	0.00
0.00	0.80	0.19	0.00	0.00	0.00	0.01	0.67	0.30	0.01	0.00	0.09	0.03	0.59	0.26	0.03	0.00
0.00	0.71	0.28	0.00	0.01	0.03	0.02	0.66	0.27	0.01	0.00	0.09	0.03	0.57	0.26	0.03	0.00
0.01	0.77	0.21	0.01	0.01	0.05	0.02	0.62	0.27	0.03	0.00	0.09	0.05	0.56	0.26	0.03	0.01
0.04	0.70	0.18	0.04	0.01	0.07	0.04	0.58	0.25	0.05	0.00	0.10	0.07	0.53	0.26	0.03	0.01
0.04	0.77	0.04	0.10	0.01	0.10	0.05	0.56	0.23	0.06	0.01	0.11	0.09	0.51	0.26	0.03	0.01
0.07	0.80	0.04	0.08	0.01	0.09	0.05	0.56	0.23	0.06	0.01	0.10	0.09	0.49	0.27	0.03	0.02
0.04	0.82	0.08	0.04	0.01	0.08	0.08	0.54	0.23	0.06	0.01	0.10	0.09	0.45	0.27	0.03	0.06
0.09	0.82	0.05	0.02	0.02	0.08	0.14	0.50	0.20	0.06	0.01	0.11	0.10	0.42	0.25	0.03	0.09
0.09	0.76	0.05	0.02	0.02	0.07	0.17	0.51	0.19	0.05	0.02	0.11	0.10	0.40	0.24	0.03	0.12
0.13	0.69	0.06	0.02	0.02	0.07	0.18	0.52	0.16	0.03	0.04	0.10	0.10	0.38	0.23	0.04	0.16

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abundance in the amount of forest as compared with the forest interior bird community suggest that patches are better than corridors to support this community, and that the more interior forest available, the better for forest interior birds. The suggested minimum amount of forest derived from these thresholds is 35% of the amount of forest within 1 kilometer of any given part of the Greenbelt. Thresholds in forest width for avian communities suggest a minimum width of 200 m for any corridor. Thresholds in distance from interior forest suggest that the forest interior bird community can be best supported by shorter corridors that connect larger patches, with a suggested maximum corridor length of 125 m.